DRIVING GREEN: EMPLOYMENT EFFECTS, POLICY ADOPTION, AND PUBLIC PERCEPTIONS OF ELECTRIC VEHICLES

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Driving Green: Employment effects, policy adoption, and public perceptions of electric vehicles

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Summary

Energy for usage in the transportation sector is primarily derived from petroleum products and accounts for 14% (EPA 2017a) of greenhouse gas emissions worldwide and 28% (EPA 2018b) of total emissions in the US. In the US. 60% of these emissions are from light-duty vehicles and passenger vehicles (EPA 2018a). A major push has been made towards alternative fuel vehicles such as electric vehicles (EVs) to mitigate the environmental impact of the transportation sector. This dissertation explores the implications of a growing EV sector by analyzing the employment effects, policy effectiveness, and public perception of EVs.

EV adoption stands to affect the overall employment in the automotive sector and allied industries. A typical EV has fewer parts and requires less maintenance than a comparable internal combustion engine (ICE) model. This differential would inevitably change the traditional model of car sales by dealers who also rely on repairs and maintenance revenues. The dissertation uses input-output modeling to examine the implications of growing EVs on employment under different scenarios and cost assumptions. The study finds that while overall employment numbers might not change significantly, the composition of jobs shifts towards more battery production and electricity generation and distribution. The second study in the dissertation examines the effectiveness of different policy choices in increasing EV adoption across states. A supportive policy environment stands to increase EV adoption. In addition to federal-level policies in the US, states have introduced several policies to increase the adoption of EVs by individual consumers and fleets. The study applies econometric analysis to a panel dataset combining EV policies with sales to examine effectiveness and design choices across states. Finally, public perception of EVs must be understood to anticipate whether these vehicles are adopted at a large scale to make an impact on the traditional industry structure. Like any new technology, EV adoption hinges on the current and potential consumers' opinions and acceptance. The dissertation uses survey data and examines the external and internal determinants of public interest in EVs. The study concludes that factors such as political affiliation, environmental efforts of respondents affect their level of interest in EV technology.

CHAPTER 1. INTRODUCTION

Energy usage in the transportation sector has local and global climate change effects. Carbon Monoxide (CO), Nitrogen Oxides (NOx) and Sulfur dioxide (SO_2) emissions from transportation reduce local air quality and contribute to global Greenhouse Gas (GHG) emissions. The growing number of private vehicles contributes to these issues and causes congestion and urban heat island effects (Kamruzzaman, Deilami, and Yigitcanlar 2018).

The transportation sector relies heavily on petroleum products for its energy consumption. This dependence on fossil fuels means that the industry accounts for 14% of GHG emissions worldwide (EPA 2017a) and 28% of the total emissions in the US (EPA 2018b). Light-duty and passenger vehicles account for 60% of these emissions (EPA 2018a). Policy nudges to reduce fuel consumption and increase efficiency include improving public transportation, reducing idling and waste, improving vehicle fuel use efficiency, and reducing the demand for traditional private transportation. Since private vehicles and cars contribute heavily to emissions from the transportation sector, analyzing the changing policies and practices, and the role of consumer attitudes provides a way to assess the implications on the energy-transportation-environment linkages. Policies are pushing towards alternative fuel vehicles such as electric vehicles (EVs), natural gas vehicles (NGVs), and fuel cell vehicles (FCVs).

Among these vehicle types, EVs have the potential to eliminate tailpipe emissions without requiring a major shift towards alternative transportation infrastructure. Batteries power the vehicles and reduce direct emissions from the transportation sector.[1] As renewable sources of energy evolve to contribute a larger share of the electricity generation mix, emissions from a more electrified transportation sector will also decline.

However, several factors inhibit the mass adoption of EVs. EVs have limited range, higher relative costs, and the existing transportation infrastructure is not designed to support vehicle recharging. This dissertation examines three aspects of the growing EV market – the impact of an increasing EV uptake on employment, the coverage and effectiveness of EV policies at the sub-national level, and internal and external determinants of public interest in EVs.

The first paper explores the effects of the EV sector on employment. Sales of EVs will affect not only the total employment in automobile and related ancillary industries, and the composition of the jobs in these sectors. The paper uses an input-output modeling analysis to estimate the potential employment effects of a typical EV available in the market today. It then uses the projected sales and costs of EVs to evaluate the expected impact in the future under high and low growth scenarios. EVs typically have fewer parts that require maintenance, rely on computation systems, smart technology, and related hardware and software. Higher sales of EVs may also lead to cascading changes across the fuel supply chain. As providers of energy for the transportation sector, the electricity and petroleum sectors will likely witness changes in the total employment and the nature of jobs in these sectors.

The second paper analyzes the evolution and effectiveness of state and local policies in driving EV sales across the US. Several state- and local-level policies are in place to support and

[1] For the rest of this dissertation, unless otherwise specified, I focus on passenger EVs that run only on electric batteries and do not have an internal combustion engine based on liquid fuels. The studies do not include e-bikes, scooters and larger freight vehicles.

encourage sales, such as providing financial incentives for purchasing EVs, providing access to parking and road infrastructure, investing in expanding the charging and refueling infrastructure needed for increased adoption of EVs. The potential inadvertent adverse effects of higher EV sales have affected state finances and caused jurisdictions to reassess these incentives. The feedback from consumers and the market has led to policy repurposing leading to variability in policy response. Some state governments are re-evaluating and changing their incentive designs while others are maintaining and even strengthening their support, and yet others have not adopted these mechanisms. These changes and the rapidly evolving sector call for a systematic assessment of policy design and its effectiveness in generating market changes. The paper combines state-level policies with EV sales and state-level factors to create a panel dataset and deploys a fixed-effects regression approach. The findings suggest that incentives are positively related to sales, but different incentive and regulation types vary in their effectiveness. The emergence of utility provided incentives also provides an alternative structure of privately provided incentives and intricacies of policy designs and interact with government-provided incentives at the state and local levels.

The third paper uses original survey data and examines beliefs, values, and attitudes, and the internal and external constraints that impact interest in EVs across five Nordic region countries. The Nordic region represents one of the top three global markets for EV mobility, after China and the United States, and, therefore, provides a unique case study for understanding public opinion. A generalized ordered logit model supported by several explanatory variables provides a highly granular assessment of these key determinants of interest in EVs. We find that social and demographic factors play an essential role in driving respondents' interest in EVs. Additionally, respondents' efforts to reduce their environmental footprint is related to greater interest in EVs.

Finally, the five countries in the survey present noteworthy variations in the factors that explain the level of interest in EVs.

1.1 A Note on the Covid-19 Pandemic and its Effect on the Transportation and Energy Sectors

Before going into the central focus of this dissertation, it is pertinent to acknowledge the relevance and response of this research project in the context of the ongoing global Coronavirus disease (COVID -19) outbreak that has already affected 215 countries, with more than 2.5 million cases, and over 254,00 deaths as of May 6, 2020 (WHO 2020). Due to unprecedented lockdowns, the resulting economic slowdown is getting reflected in the energy and transportation sectors.

The International Energy Agency (IEA) estimates that global road transport has declined between 50 and 75% (IEA 2020). Personal road mobility, the focus of this dissertation, has been substantially curtailed with social distancing and telework guidelines in place. The effects of the pandemic and associated lockdowns can be assessed in the short-medium and long-term. The short-term, in the US, the year-on-year road passenger transport activity was nearly 57% of the past year. Since the transportation sector constitutes 60% of the global petroleum usage, the oil markets have witnessed a decline with global demand falling by nearly 5% (IEA 2020).

The decline in mobility, although projected to be temporary, will impact automotive markets in the medium term. First, even as the demand for mobility services has declined, the reliance on driving has declined the least in the US and is closer to returning to normal as of May 05 than the alternative of public transit (Apple 2020). Further, although global car sales declined worldwide in response to the economic slowdown, the EV market witnessed a more mixed result – while sales have not declined in the European Union due to the emission requirements, sales in China, India and the US have declined rapidly (IEA 2020). As global crude oil prices reached unprecedented low levels in recent history in April 2020, the average gasoline prices reflected the decline, falling from $2.49/gallon on January 06 to $1.75/gallon as of May 11, 2020 (EIA 2020a). this decline is projected to continue for the rest of the calendar year as demand for gasoline remains low. However, as the global economy returns to a "new-normal", and passenger transport activity and demand increases again, potentially in early 2021, we could expect an increase in the price of petroleum and as a result, a potential resurgence in demand for alternative fuel vehicles. While the dissertation does not directly deal with this rapidly evolving situation, the different chapters do address the potential effects that the economic downturn could have on the sector, and how future research could potentially take these into account.

The rest of the dissertation is organized as follows. Chapters 2 examines the first aspect – estimating in detail the total and distributional employment effects of EV sales under different scenarios. Chapter 3 then looks at the evolution and effectiveness of state and local EV support policies. Chapter 4 analyzes the role of public perceptions and factors that drive levels of interest in EVs. Finally, Chapter 5 summarizes the findings and ties the research questions together.

CHAPTER 2. EMPLOYMENT IMPACTS OF INCENTIVIZING ELECTRIC VEHICLES: DOES PROMOTING VEHICLES CREATE JOBS?

2.1 Introduction

The EV market witnessed a rapid uptake starting in 2010, with the introduction of more affordable mass-market light-duty EVs such as the Nissan Leaf and Tesla Model S. The most optimistic projections put the global EV market as high as 600 million EVs by 2025 (BNEF 2019). In the US, the share of EVs could rise from 1.2% in 2018 to 7.6% of new vehicle sales in 2026 (Brinley 2019). Growing interest from manufacturers, a supportive policy environment, and improved public perception of EVs show promise for transforming the transportation sector and, reducing transportation-related GHG emissions (Lee, Thomas, and Brown 2013).

A growing EV market may have a substantial impact on employment in the automobile industry and allied sectors. The Bureau of Labor Statistics indicates that the "Transportation equipment manufacturing" employs 1.7 million people (NAICS 336), and another 2.1 million people work in the "Motor Vehicles and Parts Dealers" sector (NAICS 441) (BLS 2020a, 2020b). Wider adoption of EVs is likely to have implications not just for the transportation and fuel sectors but also for other related industries due to the backward and forward linkages in manufacturing and tertiary industries. Growth of EV sales will also boost the computing abilities of cars and the associated hardware and software industries. Jobs in the petroleum sector are likely to decline but electricity and battery manufacturing jobs should grow, and likely result in positive spillovers in the power and primary energy sectors.

This paper addresses two questions – (1) how will a growing EV sector affect employment in the US automobile sector? And (2) how will the jobs be redistributed across various sectors following a shift towards EVs? By answering these questions, the study contributes to the literature on the economy-wide effects of sustainable transitions in energy and transportation (UNEP 2008; Pollin et al. 2014; Vona 2019; ILO 2018).

2.2 Literature

The literature has examined how climate policies impact total jobs, their changing nature, and the skill requirements (Giovanni Marin and Vona 2019b; Consoli et al. 2016; Vona 2019; Pollin et al. 2014; Vona et al. 2018; Aldy and Pizer 2015). Academic literature on employment in the EVs sector is relatively sparse, however. Accounting for this gap, I expand my review of the literature in two ways – by examining prior work on sustainability-related jobs rather than focusing only on EVs and by including research outside academic and peer-reviewed publications to incorporate reports and grey literature.

2.2.1 Green Jobs Literature

The literature on jobs in sustainability, especially in renewable energy and energy efficiency (also referred to as *green jobs*), covers a wide range of sectors and methodological approaches. Studies examine the effect of alternative energy sources and energy efficiency on employment by deploying input-output (I-O) modeling (Garrett-Peltier 2017; Baer, Brown, and Kim 2015), computable general equilibrium models (Dai et al. 2016; Brown, Li, and Soni 2020), meta-analyses (Fankhauser, Sehlleier, and Stern 2008), case studies, and econometric analyses (Yi 2013; Blazejczak et al. 2014). These studies have been conducted at the city (Yi 2013), state, and national (Garrett-Peltier 2017) levels. The analysis also covers a wide range of economic sectors and industries such as combined heat and power (Baer, Brown, and Kim 2015), solar photovoltaics in Spain (Llera et al. 2013), renewable energy (Garrett-Peltier 2017; Blazejczak et al. 2014) and energy efficiency (Garrett-Peltier 2017). Most studies find that clean energy deployment increases total employment (Yi 2013; Garrett-Peltier 2017; Markaki et al. 2013), and decreases GHG emissions (Lee, Thomas, and Brown 2013).

2.2.2 Employment in the Automotive Sector

Employment in the automotive sector goes beyond just manufacturing and includes other allied industries such as repairs and maintenance, automotive fuel sector, and financing and insurance. The US Energy and Employment Report (USEER) provides a comprehensive analysis of employment in the energy sector in 2017 (NASEO and EFI 2018; DOE 2017). The report states that out of 2.46 million people employed in the motor vehicles sector in the US, the largest share of jobs was in "Manufacturing" (39.7%), followed by "Repairs, Maintenance, and Other Services" (37.8%). Another two million people worked in dealerships and retail sectors. The report also states that 219,661 jobs in motor vehicles were in the "Alternate Fuel Vehicles" sector, of which a little over 11,000 jobs were in electric vehicles.

Manufacturing and maintenance are the two main components of the EV sector. In manufacturing, 4,210 jobs in 2017 were in the production of "parts," and 7,313 jobs were in producing the automobiles themselves. Within repairs and maintenance, 11,305 jobs were in "component parts and repairs" and four times as many (45,024) were in repairs of motor vehicles.

Early studies focusing on EVs and their impact on employment barely explored this aspect. Evidence was limited to general statements about the potential loss of jobs to international markets and varying effects on policymakers and manufacturers. Tollefson (2008) identified the potential loss of jobs in the EV battery market where the jobs could be lost to Asian markets, which have gained a foothold in lithium-ion battery manufacturing. He did not go beyond just looking at this initial status. Dijk and Yarime (2010) studied the introduction of a new electric vehicle engine from the perspective of policymakers as a source of new employment. The authors state that while from the perspective of manufacturers, the market for electric car engines was uncertain, policymakers would be more interested due to the potential implications on employment. However, the authors do not explore this question in greater detail beyond this fleeting mention.

Conducting a simulation analysis of the growing clean energy vehicle market in Japan, Osawa and Nakano (2016) and find that the total effect of these vehicles varies over time and across industries; while the initial employment gains are high but decline by 2030. The authors Some industries grow (“Other Electrical Equipment,” “Civil Engineering and Construction,” and “Electricity” Sectors) but “Motor Vehicle Parts and Accessories” industry witnesses the most significant losses in employment. Job losses occur because EVs have fewer parts and require less maintenance. Using an input-output model automobile supply chain sectors in the UK, Turner et al. (2018) conclude that the relatively lower import intensity of the power sector means that with more EVs, the UK will gain more jobs. The expansion of the domestic sector from the second- and third-order effects will bolster the projected gain from higher EV sales.

Finally, although not a focus of this study, the work on estimating the effects of sustainability transitions has broad implications across the fields of industrial development, health and the economy. Studies in the field of health, industry and social policy find causal linkages between employment uncertainty and mental health, effects of automotive industry on welfare policy, and re-emergence of rust belt cities (Kim and Kim 2018; Lopez et al. 2012; Anaf et al. 2013; Fasenfest and Jacobs 2003).

In sum, while there is some literature to indicate what a future market with higher numbers of EVs might look like, the analysis is limited in scope, temporal, and regional coverage. From the available evidence, the consensus seems to be that there will be a change in the distribution of employment across different sub-sectors in the economy, particularly in the supply chain industry where sectors that provide fuel (petroleum and electricity), and the manufacturing of these fuels (batteries, and petroleum) will witness a shift.

2.3 Research Questions and Hypotheses

This study aims to answer two research questions. This first question takes a broad view of the EV sector to estimate the implications of the sector's growth on employment.

- What is the total effect of increasing Electric Vehicle sales on employment in the US?

Based on the literature, the paper tests the following hypothesis.

Hypothesis 1: Increasing EV sales will have minimal effects on total employment in the automotive manufacturing sector

The second research question looks at the implications of a shift in production components and the spending on vehicle operation.

- How is this effect distributed across different industries/sub-sectors?

The associated hypotheses are as follows.

Hypothesis 2a: Increase in EV sales will lead to a shift away from manufacturing-intensive jobs towards battery- and technology-related jobs in capital spending

Hypothesis 2b: The shift in operations and maintenance (O&M) expenses will be higher since EVs require spending on very different categories of industries

2.4 Methodology

2.4.1 Input-Output modeling to examine the employment effects

Input-output (I-O) modeling gives a snapshot view of the economy and can be used to assess how changes in one sector affect the entire economy. I-O models relating to green jobs have been used to examine the effects on GDP, employment, and other economy-wide indicators (Miller and Blair 2009; Garrett-Peltier 2017).

The I-O approach relies on exchange among different industries in an economy. The entire economy is represented using a matrix of inputs used to produce outputs. To compute the employment effects, we start with the Leontief Inverse Matrix that represents the inputs needed to produce a dollar of output in each industry (Leontief 1936; Garrett-Peltier 2017). The analysis begins with the n x n matrix A that represents the economy. Each element of the matrix A, $a_{ij} = x_{ij}/x_j$ which represents the inputs needed from industry i to produce one unit of output for industry j. In the symmetric Leontief Inverse Matrix ($(I-A)^{-1}$), the rows represent the inputs to produce the outputs represented in columns. The coefficient matrix is then post-multiplied by a final demand vector that represents (ΔY) the change in output for different industries owing to the increase in investments. To generate the employment effects, we start with the economy-wide *1xn* vector e of employment multipliers where each element e_i represents the full-time equivalent (FTE) employment needed to generate one unit of output for industry i. The post-multiplication product ($e(I-A)^{-1}$) provides the total employment effects of investments in the economy.

Given this explanation of the I-O modeling approach, it is also important to note certain limitations that this methodology imposes. The first two limitations emanate from the static nature of I-O tables and coefficients. First, the price changes that are dynamically responding to the current economic situation highlighted in Chapter 1 are not visible in the present study. Second, an increase in the demand for electricity to charge EVs will also affect the electricity markets which are not considered in this analysis. Third, the modeling approach assumes a constant returns-to-scale, which implies that the evolving nature of EV market is not taken into account. As EV manufacturers increase their production, they are likely to witness economies of scale and scope. In the current set-up, we are unable to account for this change. A computable general equilibrium approach would be better positioned to answer these questions.

IMPLAN is an I-O modeling software that aggregates across different North American Industrial Classification System (NAICS) code industries to form 536 sectors (IMPLAN 2017). Users can also create industries within the model and leverage the existing structure of the economy to compute cross-industry changes and the overall effects on other macroeconomic indicators.

The current structure of the IMPLAN model does not include a separate sector for EVs. Additionally, even for sectors included within the modeling system, it is difficult to identify the distribution of inputs across different sub-sectors given the high level of aggregation in the model structure. This paper uses a list of the main components and inputs for a typical compact EV to analyze the capital as well as operational expenses for the vehicle. Then, using the costs of these vehicles and available information on the distribution of different components, the paper distributes the share of different IMPLAN sectors for the typical EV. The approach is a combination of the "synthetic approach" used in Garrett-Peltier (2017) and the "bill of goods" used by Baer, Brown, and Kim (2015), and Brown, Li, and Soni (2020). For the comparable ICEV, the paper analyzes at the default distribution of jobs in the category "Automobile Manufacturing" within the IMPLAN system.

The next step is to compute the employment effects of these two competing industries by creating a sector within the IMPLAN modeling framework. A multiplier indicates the factor by which employment will increase with an increase in spending/investment in the sector. For instance, if the employment multiplier associated with a sector is 1.5 per million dollars, this implies that an investment of $1 million in that sector will generate 1.5 full-time equivalent (FTE) jobs for the economy. The analysis generates three types of employment effects – direct, indirect, and induced, as described below.

- The ***direct effects*** represent the total impact on sectors that get affected by direct spending due to the creation of a new industry. In the case of EVs, for instance, manufacturing more EVs will directly generate jobs in vehicle manufacturing.
- ***Indirect effects*** primarily include the materials and industry demand as a second-order effect. The spending in vehicle manufacturing leads to indirect gains in inputs such as steel, metal stamping, and wholesale trade.
- Finally, ***induced effects*** reflect the increased spending on consumer goods and services by those earning higher incomes due to the direct and indirect effects across the economy. For EVs, the gains made by the direct and indirect beneficiaries of EV production get reflected through increased consumer spending in restaurants, hotels, recreation, etc.

The total effect is computed by aggregating the three effects and jobs generated across each sub-sector. Sensitivity checks examine how different ranges of vehicle prices, especially given the projected decrease in battery costs in the next two decades (BNEF 2018a; Nykvist and Nilsson 2015). This paper uses investment levels to calculate the employment effect; to account for the projected decline in the capital cost of EVs (driven primarily by lower battery costs), the paper also considers the effects of a level of investment in the EV market under different cost distribution scenarios. However, to examine the distributional effects of operations and maintenance expenditure on electric vehicles, the paper uses the distribution for a typical EV and scales it up to 1000 EVs to compare with the ICEVs that a typical EV is expected to replace. The following sub-section details the inputs and cost distribution used in the analysis.

2.4.2 List of inputs

This section summarizes the methodology for developing the list of inputs for EVs. The key sub-sections are the capital cost, i.e., the cost of purchasing the vehicle upfront; the second is the operations and maintenance expenses.

2.4.2.1 Capital Expenses

Capital costs of EVs come from three sources – the assessment of vehicle costs by Lutsey and Nicholas (2019), the analysis of a Chevrolet Bolt by Hummel et al. (2017), and the analysis of a typical mid-size EV by Kochhan et al. (2014). The direct powertrain and other direct costs form the two main cost categories. The first includes battery costs, drivetrain, and powertrain expenses, and onboard chargers. Other direct costs include the costs of assembling, warranties, supplier components (Figure 2-1).

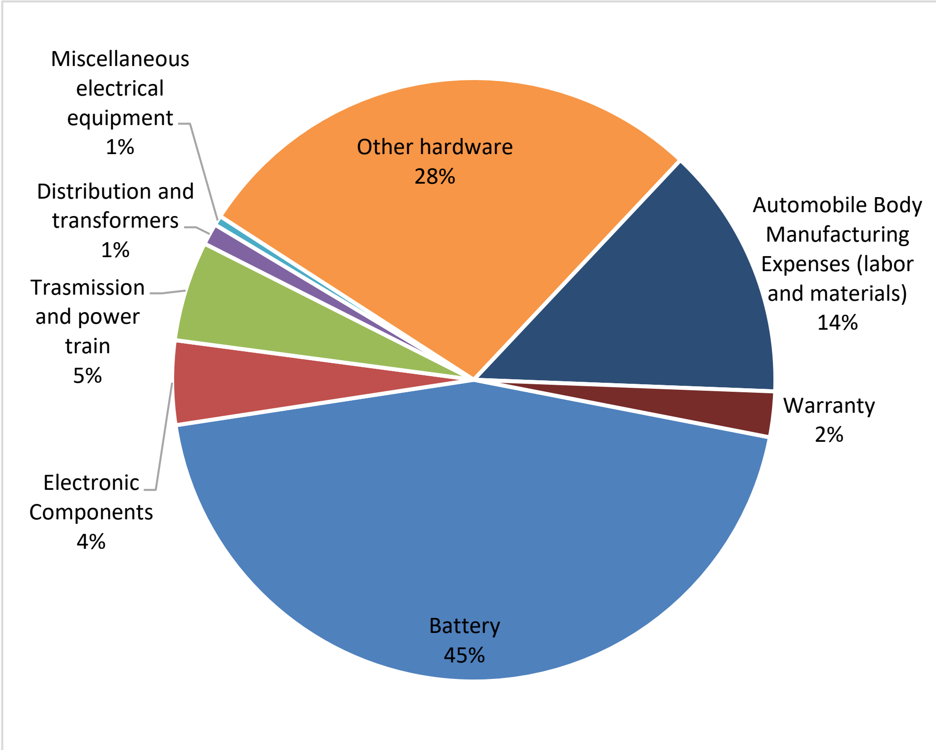


Figure 2-1: Components of Capital Expenses for a mid-size Electric Vehicle

Battery cost is the most significant component of EV capital expenses. The next component by magnitude is hardware, followed by the automobile body manufacturing expenses (including labor and materials), various other components, including the electric powertrain and inverter, as well as warranty and other hardware.

2.4.2.2 Operations and Maintenance Expenses

The paper considers a 5-year timeline to compute the operations and maintenance expenses using a 5% discount rate, and 2% inflation rate. The same approach is used for both EVs and ICEVs. However, the cost distribution and total spending are different for the two technologies. The distance traveled by an average vehicle is determined based on the National Household Travel Survey (ORNL 2016). The distance traveled is based on the distribution of miles traveled across US car drivers (Table 2-1). Based on the survey, the total annual distance driven is 13,497.7 miles (36.98*365).

Table 2-1:Distribution of traveler and vehicle miles traveled each day

% share of travelers (A)	Vehicle miles traveled (B)	(A*B)
1	1	1
9	3	27
22	10	220
25	23	575
15	38	570
10	53	530
13	90	1170
5	121	605
Average vehicle miles traveled		**36.98**

Source: ORNL (2016)

The O&M expenses have three main components – the cost of fuel, repairs, and maintenance, and insurance expenses. The American Automobile Association (AAA) provides estimates for these expenses in its annual brochure. For robustness, the analysis also matches the AAA estimates with the True Cost to Own® for representative car models from Edmunds (Edmunds 2020). Table 2-2 summarizes these costs for both ICEVs and EVs.

Repairs and maintenance – The AAA estimates a per-mile cost of 7.6 cents per mile (for an annual driving distance of 10,000 miles) for repairs and maintenance expenses for an EV (AAA 2018).[2] This is adjusted to account for the assumption of an average Vehicle Miles Traveled (VMT) of 13,497.7 miles (Table 2-1).

[2] The electric vehicle represented in the AAA calculations are BMW i3, Chevrolet Bolt, Fiat 500e, Kia Soul and Nissan Leaf.

Insurance –The rate for 2018 was $1215, and it increases at the inflation rate of 2% every year (AAA 2017).

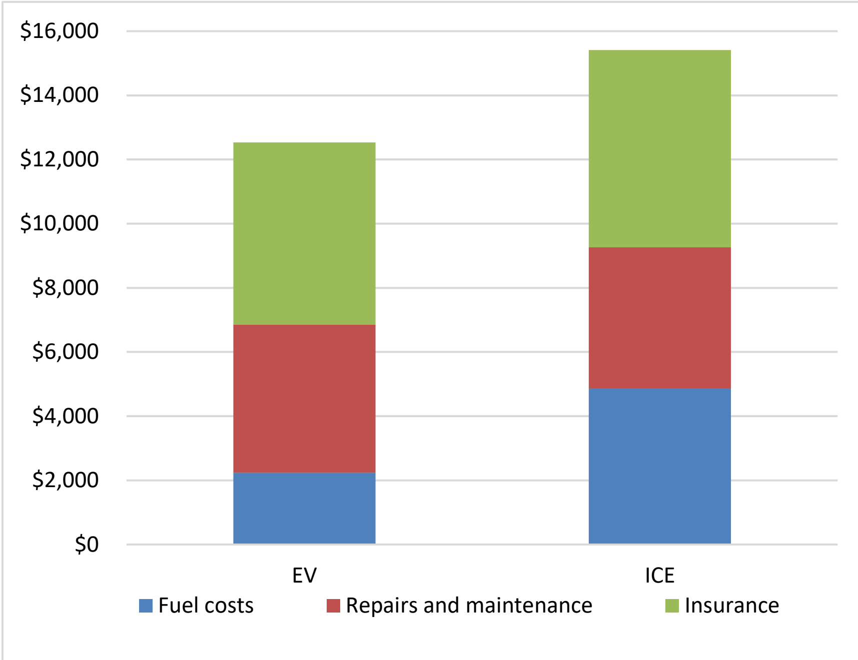


Figure 2-2: Components of O&M Expenses for a compact Electric and Internal Combustion Engine Vehicle

Fuel cost – For EVs, the analysis uses the cost of electricity as identified by AAA. The fuel cost is as 3.68¢/mile. For ICEVs, AAA provides a cost of 8.01¢/mile. This provides the baseline for the first year, and then an inflation rate of 5% is used for the future years. The Federal Electric Utility sector in the industry list provides the inflation rates.

2.5 Results

2.5.1 Analysis of Capital Expenses

I create a new activity in the software called "Electric Vehicles Manufacturing" and distribute the share of output in the ratios represented in Figure 2. Using this distribution, I create a Scenario within IMPLAN to estimate the implications of investing in the manufacturing/purchase of EVs. As noted earlier, to maintain comparability (accounting for the projected reduction in the cost of EVs and the relatively stable cost of ICEVs), I use the levels of investment and calculate the total jobs generated with $ 1 million invested in the sector in the year 2018. Table 2-2 presents the results of the scenario run with the total change in jobs. The Table also includes the top ten sectors that contribute the most to employment. Several other sectors contribute to the overall number due to the second- and third-order effects. A one-time investment of $1 million in this sector generates a little over nine full-time-equivalent jobs. As an example, considering Sector 356 – "Other motor vehicle parts manufacturing." The sector generates a total of 0.60 FTE jobs. Of these, 0.54 are the result of direct spending within the sector, and an additional 0.06 jobs are a result of indirect spending for manufacturing other motor vehicle parts. These would include the resources spent in the sector. In many sectors, the indirect and induced effects are strong and outweigh the direct effects – for example, sector 501 – "Full-Service Restaurants" and 502 – "Limited-Service Restaurants" where induced spending jobs gains outnumber the direct jobs (0) and indirect jobs (0.04). In addition to the ten largest sectors presented here, the $1 million get distributed across 168 industries in the model.

Table 2-2: Total employment effects of $1 million in EVs (high battery costs)

Sector	Description	Direct	Indirect	Induced	Total
	Total	**1.61**	**3.68**	**3.75**	**9.05**
	Top 10 sectors				
337	Primary battery manufacturing	0.82	0.00	0.00	0.82
356	Other motor vehicle parts manufacturing	0.54	0.06	0.00	0.60
395	Wholesale trade	0.00	0.42	0.11	0.53
461	Management of companies and enterprises	0.00	0.19	0.04	0.23

440	Real estate	0.00	0.06	0.16	0.23
501	Full-service restaurants	0.00	0.04	0.16	0.20
502	Limited-service restaurants	0.00	0.03	0.15	0.18
411	Truck transportation	0.00	0.14	0.04	0.18
468	Services to buildings	0.00	0.09	0.06	0.15
482	Hospitals	0.00	0.00	0.15	0.15

Battery manufacturing is not a labor-intensive industry, and the indirect and induced effects in this scenario reflect this. Since the sector currently contributes nearly 45% of the total cost of an EV, there is room to explore the potential effect of falling battery prices on employment.

2.5.1.1 Comparison with ICEVs

The next step is to compare this industry with the jobs generated in the ICEV market. As noted earlier, the default IMPLAN system includes industry for Automobile Manufacturing. The component sectors within the model also include the distribution across sectors that would benefit from indirect and induced effects of higher sales. Keeping the baseline investment of $1 million to compare it with the EV sector, I run the analysis by creating a scenario with the investment in one time-period. Table 2-3 summarizes the results from this analysis.

Table 2-3: Total employment effects of $1 million in ICEVs

Sector	Description	Direct	Indirect	Induced	Total
	Total	**0.65**	**4.65**	**3.88**	**9.17**
	Top 10 Sectors				
395	Wholesale trade	0.00	0.65	0.11	0.76
343	Automobile manufacturing	0.65	0.01	0.00	0.66
461	Management of companies and enterprises	0.00	0.27	0.04	0.31
440	Real estate	0.00	0.07	0.17	0.24
501	Full-service restaurants	0.00	0.04	0.17	0.21
411	Truck transportation	0.00	0.16	0.04	0.20
502	Limited-service restaurants	0.00	0.03	0.15	0.19
355	Motor vehicle metal stamping	0.00	0.19	0.00	0.19
354	Motor vehicle seating and interior trim manufacturing	0.00	0.17	0.00	0.17
482	Hospitals	0.00	0.00	0.16	0.16

Comparing the results from Table 2-4 and Table 2-3, the spending on batteries for EVs is the largest source of difference in the total employment effects. Among the top 10 sectors, the most significant differences are in battery manufacturing, followed by the wholesale trade sector. Since fewer parts in EVs explain this difference.

2.5.2 Analysis of Operations and Maintenance Expenses

In comparing the O&M expenses for the two vehicle-types, I follow a slightly different approach where instead of examining the effect of spending a million dollars, I look at the average EV expenditure for one vehicle and then scale it up to compare 1000 EVs with ICEVs. Effectively, the comparison here is between the O&M spending on 1000 EVs vis-à-vis a 1000 ICEVs. Further, instead of sorting the spending by just the total effect, I first sort it by the direct effect, and then the total effect. This approach allows us to compare across the different components of O&M expenses. Table 2-4 and Table 2-5 provide a comparison. The fuel expenses are significantly lower for EVs than in ICEVs.

Table 2-4: Total employment effects of O&M spending on 1000 ICEVs

Sector	Description	Direct	Indirect	Induced	Total
	Total	**86.28**	**41.22**	**68.37**	**195.87**
	Top 10 sectors				
504	Automotive repair and maintenance, except car washes	44.87	0.12	0.91	45.89
438	Insurance agencies, brokerages, and related activities	32.21	16.52	0.83	49.56
402	Retail - Gasoline stores	9.19	0.07	0.47	9.73
440	Real estate	0.00	2.84	2.95	5.80
501	Full-service restaurants	0.00	0.95	2.96	3.90
502	Limited-service restaurants	0.00	0.27	2.73	3.00
482	Hospitals	0.00	0.00	2.74	2.74
395	Wholesale trade	0.00	0.79	1.93	2.72
464	Employment services	0.00	1.41	1.22	2.63
436	Other financial investment activities	0.00	0.59	1.36	1.96

Table 2-5: Total employment effects of O&M spending on 1000 EVs

Sector	Description	Direct	Indirect	Induced	Total
	Total				
	Top 10 Sectors				
504	Automotive repair and maintenance, except car washes	47.03	0.11	0.93	48.08
438	Insurance agencies, brokerages, and related activities	29.76	15.28	0.86	45.9
519	Federal electric utilities	1.66	0.01	0.01	1.68
440	Real estate	0	2.64	3.04	5.68
501	Full-service restaurants	0	1.03	3.05	4.07
502	Limited-service restaurants	0	0.27	2.82	3.09
395	Wholesale trade	0	0.9	1.99	2.89
482	Hospitals	0	0	2.82	2.82
464	Employment services	0	1.48	1.26	2.74
436	Other financial investment activities	0	0.59	1.41	2

To sum up, while the overall employment in the O&M sector might not change much as the market evolves with a move from traditional ICEVs to EVs will only have marginal effects on the total employment levels in the economy. However, this shift from conventional to alternative vehicles will lead to a shift across sub-sectors with some winners and losers. As the preceding analysis indicates, the most notable difference here is in the fuel expenditures of the two types of vehicles – ICEVs contribute to the petroleum sector whereas the fueling costs of EVs are a considerably lower share of the overall expenses and even this lower share get targeted towards a different industry - electric utilities. With the potential inter-industry substitution and changes highlighted in the analysis, the results also present the possibility of significant distributional and equity implications.

2.5.3 Sensitivity Analysis

This section analyzes two different estimates to examine the implications and the sensitivity of this industry to changing structures – 1) reducing the share of primary battery costs in the capital costs of the EVs, and 2) using the projected prices and sales of EVs to estimate the employment in future years. The following sections consider some alternate and future scenarios.

2.5.3.1 Reduced Battery Costs

In the alternative scenario, battery costs form 25% of the total EV cost. The remaining 75% gets distributed across all sectors in the original proportion from Table 2-1/Figure 2-1. Table 2-6 summarizes the results.

Table 2-6: Total employment effects of $1 million in EVs (with a lower share of battery costs)

Sector	Description	Direct	Indirect	Induced	Total
	Total	**1.69**	**4.23**	**4.17**	**10.09**
	Top 10 Sectors				
356	Other motor vehicle parts manufacturing	0.72	0.09	0.00	0.81
395	Wholesale trade	0.00	0.47	0.12	0.59
337	Primary battery manufacturing	0.46	0.00	0.00	0.46
461	Management of companies and enterprises	0.00	0.24	0.05	0.28
440	Real estate	0.00	0.07	0.18	0.25
501	Full-service restaurants	0.00	0.04	0.18	0.22
502	Limited-service restaurants	0.00	0.04	0.17	0.20
411	Truck transportation	0.00	0.15	0.04	0.19
482	Hospitals	0.00	0.00	0.17	0.17
464	Employment services	0.00	0.09	0.07	0.17

Here, the total employment increases by nearly 1 FTE job in the first scenario. The most significant contributor to overall employment in this context is “Hardware Manufacturing,” followed by “Wholesale Trade.”

Another way to interpret this result is that at the current price of batteries, vehicle sales are lower, and this gets reflected in the jobs generated. As the costs of batteries fall in the future, assuming all else remains constant, sales will increase, resulting in job creation (IEA 2018a; BNEF 2018a). Curry (2017) provides one of the most optimistic estimates, projecting the share of batteries in total vehicle costs to fall from 48% in 2016 to 18% by 2030.

Finally, comparing the distribution of employment across the aggregate sectors of the economy, Table 2-7 presents the comparison for the high and low battery price scenarios. The most considerable difference in the two scenarios is in the Services sector employment. The distribution impacts reflected in the induced effects of different sectors drive this difference.

Table 2-7: Aggregate Effects of EVs

	High Battery Cost	Low Battery Cost
Total	**9.0**	**10.1**
Agriculture	0.1	0.1
Mining	0.1	0.1
Construction	0.1	0.1
Manufacturing	3.1	3.4
Transportation, information and public utilities	0.6	0.6
Trade	1.1	1.2
Service	3.9	4.5
Government	0.1	0.1

2.5.3.2 Projected EV Sales and Prices

This section looks at the predicted sales and prices from the Department of Energy's Annual Energy Outlook (EIA 2020b) to predict the potential employment gains in the sector in the long-term. According to the Outlook's projections, sales of 300-mile range EVs are expected to increase at an annual rate of 5.1% by 2050, and the prices are expected to decline by over $10,000 in the 25 years between 2025 and 2050 (Figure 2-3). These numbers provide an estimate of the total market size for the EVs and then compute the employment generated for the years 2030, 2040, and 2050. Also, to create an upper bound for the estimates, the analysis uses the projected sales scenario due to a $35 CO_2 fee. The sales in this scenario are 4%, 7%, and 13% higher in 2030, 2040, and 2050, respectively, than those in the reference scenario. The projected new sales in 2050 reach a little over one million in the reference scenario, and a little under 1.2 million in the carbon fee scenario.

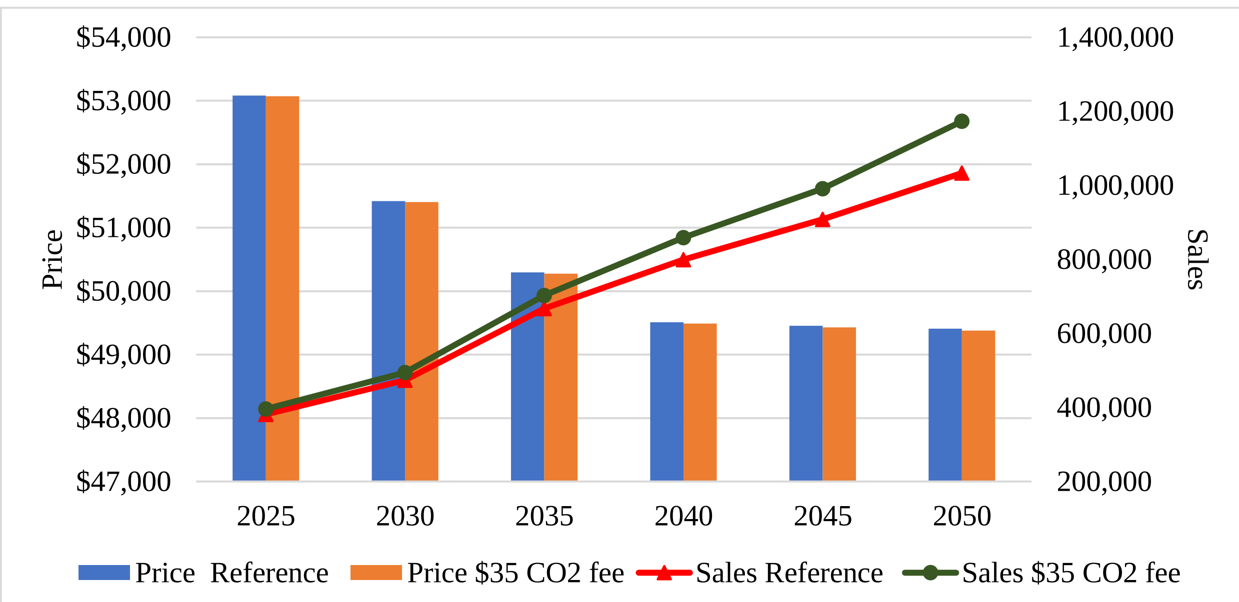


Figure 2-3: Project Sales and Prices of 300-mile range EVs
Source: EIA (2020b)

Figure 2-4 presents the total employment generated in the next three decades and the top 10 sectors where these jobs will be. With the current distribution across vehicle components, "primary battery manufacturing" and "motor vehicle parts manufacturing" sectors will likely witness the most substantial gains in employment, followed by wholesale trade. The relative gains in the 2030s are higher than those in the 2040s, but the total number of jobs in 2050 reach nearly 250,000. Examining the employment effects of the projected carbon fee scenario (Figure 2-5), with higher EV sales, jobs in the sector would increase to over 450,000 and 615,000 by 2040 and 2050, respectively.

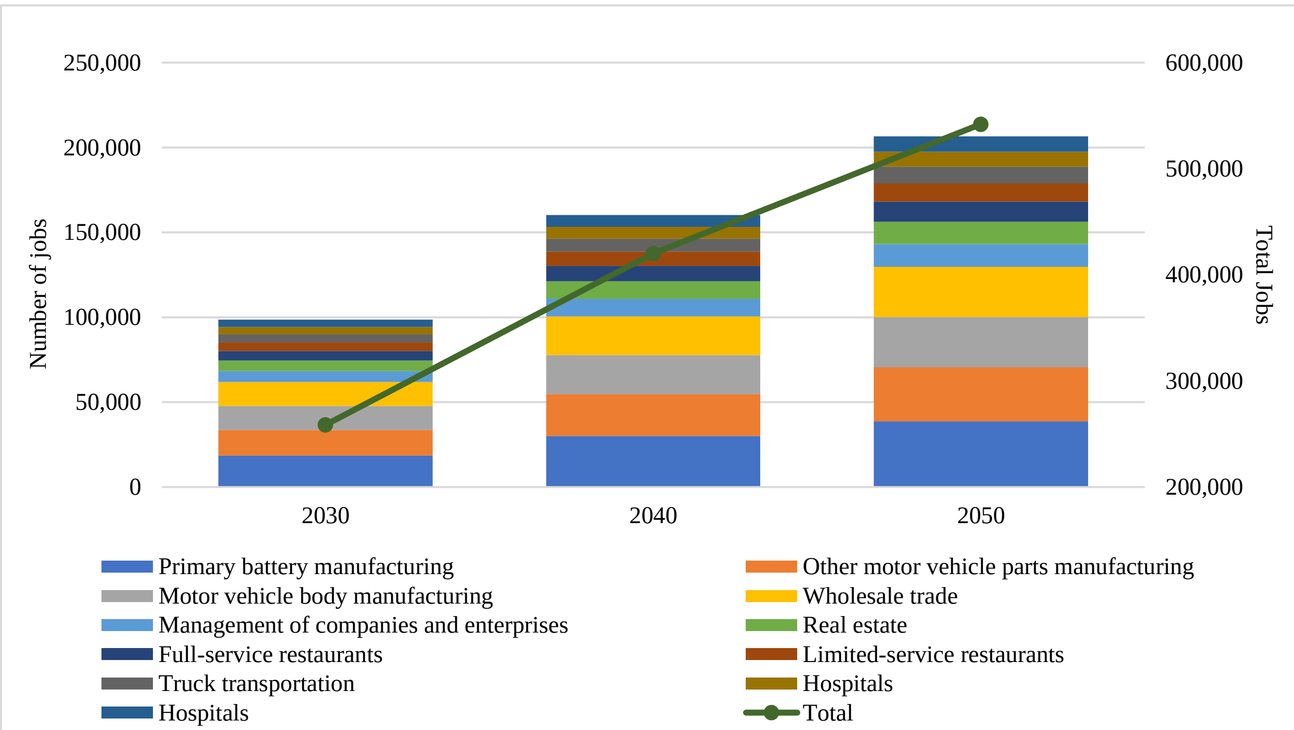


Figure 2-4: Jobs generated in the reference scenario

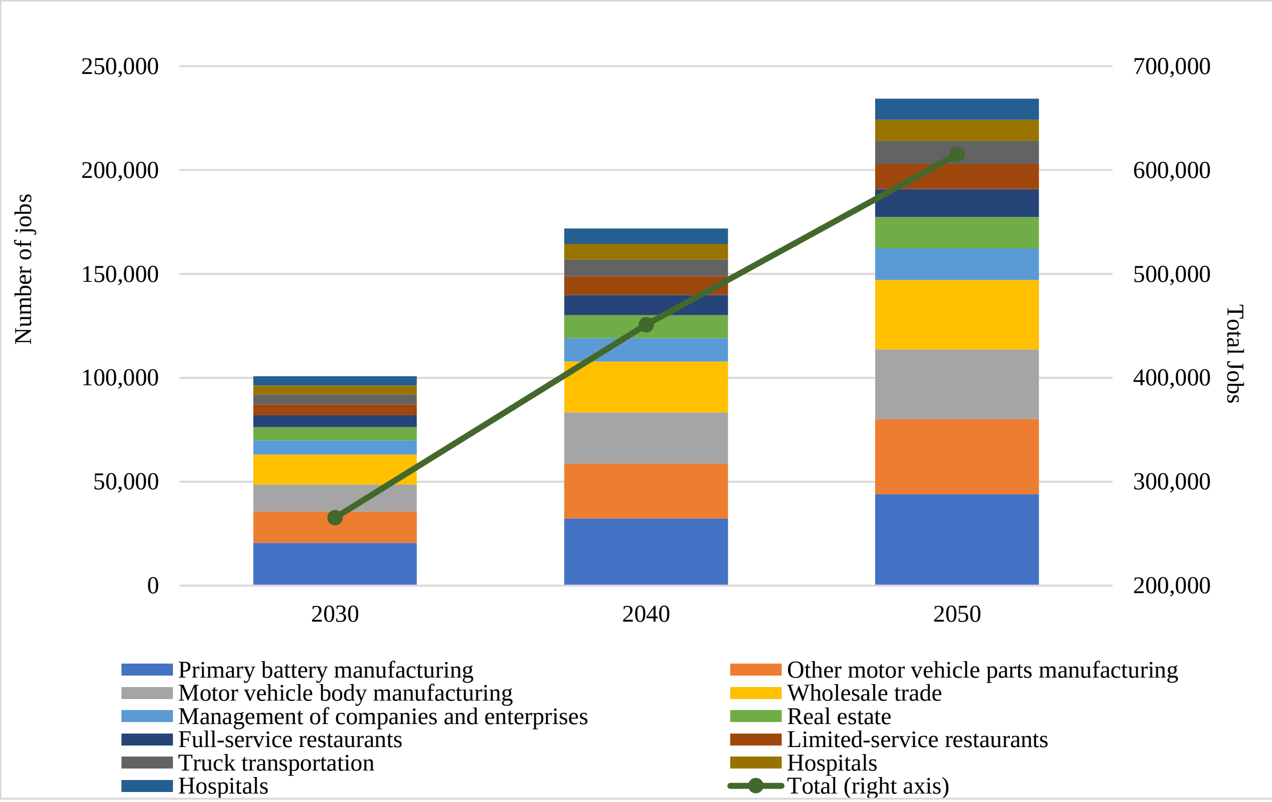


Figure 2-5: Jobs generated with a $35 carbon fee

2.6 Discussion and policy recommendations

This paper explores the potential effects of a changing and more electrified light-duty vehicle sector. As more consumers purchase EVs, there are likely to be ripple effects for those employed in the automobile sector all along the value chain. Some conclusions emerging from the analysis are summarized below.

1. ***Capital Costs of EVs***:
    a. Total employment is likely to remain unchanged as a result of the shift from ICEV manufacturing to EV manufacturing

   b. Primary battery manufacturing will gain in the initial years as the cost of batteries is higher
   c. Over time, as the share of batteries declines, EVs might even lead to higher employment than the traditional ICEV manufacturing
2. ***Operations and Maintenance Expenses:***
   a. The gains in the capital expenses might get reversed when we consider the changes in the fuel and O&M value chain.
   b. The shift from ICEVs to EVs will certainly have distributional implications across sectors, specifically away from petroleum and towards electric utilities.

While the total employment might not change much, increased manufacturing of EVs leads to an increase in the demand and manufacturing of batteries, leading to a more significant gain in employment in the sector. However, primary battery manufacturing is not a labor-intensive sector and, therefore, has limited indirect and induced effects in terms of employment. Further, as the costs of batteries reduce, this composition will change again, away from batteries and manufacturing of automobile parts.

More significant changes may, however, arise due to the difference in the composition of operations and maintenance spending for the two sectors, especially for the expenditure on fuel. The total employment generated in electricity sales is much lower than the direct effects on fuel spending on gasoline in ICEVs. This finding provides a potential need to design policies for the workers' employment and training in these sectors. This finding also confirms previous analyses on the changing and perhaps increased skill requirements brought about by the shift to green jobs (Böhringer, Keller, and van der Werf 2013; Consoli et al. 2016; G. Marin and Vona 2019a).

Employee retraining policies and welfare-to-work programs can be designed to target specific cohorts in the labor market.

Lastly, another potential distributional implication is the geographic distribution of a shift in employment. The automobile manufacturing sector has already witnessed a decline and a geographic realignment in the US, with the emergence of the rust belt area, which formerly relied on employment in automotive manufacturing. With a move towards EVs, the same trends might emerge with a redistribution of employment across regions that have traditionally been the hubs of car manufacturing in the US and newer regions emerging as dominant producers of vehicles and batteries.

CHAPTER 3. ARE ALL INCENTIVES CREATED EQUAL? ROLE OF POLICY DESIGN IN STATE LEVEL ELECTRIC VEHICLE SALES

3.1 Introduction

The private transportation sector, in particular light-duty passenger vehicles, provides an example of private decisions affecting public goods where an individual's choice of vehicles for their use generates environmental externalities and therefore requires the use of policy instruments to correct for the market failure (Goulder and Parry 2008).

The federal, state and local governments offer various incentives to encourage an increase in the adoption of EVs. These include monetary incentives such as tax credits, preferential treatment for EVs such as parking spots, infrastructure support through charging networks and electricity rate reduction, and regulatory benefits such as exemption from emissions testing. As of November 2019, 857 policies had been implemented, superseded or amended across the US. State EV policy response reflects a combination of fiscal and environmental federalism (Oates 2001), a way of addressing local conditions and, in recent years, a response to the vacuum created by the withdrawal of federal policymaking in the environmental arena.[3] States follow different paths towards introducing these policies based on the triggering events (local air pollution, larger climate change goals). When the first policies were introduced following the Alternative Motor Fuels Act of 1988 and the Clean Air Act Amendment rules in 1990, pollution from vehicles was high on the policy agenda (Collantes and Sperling 2008). However, technology in this space was nascent at

[3] States and cities have issued climate plans in keeping with the Paris Climate Accord, issued local level renewable energy policies, and joined national and international networks of business and policymakers to continue working towards the global goals for limiting climate change.

the time and policy largely focused on technology adoption via mandates. In addition, states also adopted policies to define the different alternative fuel vehicles (AFVs) in the early years.

More recently, the American Recovery and Reinvestment Act (ARRA) funding aimed at increasing the economic effects and generate employment from investments in the sector. Starting in 2015, the Volkswagen (VW) Settlement (EPA 2017b) provided funds and a direction to develop EV capabilities across the country. The multiple sources of funding also facilitated state adoption of EV related policies and investment in infrastructure to spur growth and sales of these vehicles. Important to note here is the emergence of state and local policymakers as the drivers of policy innovation and adoption in this field.

This paper examines the trends in policies over time and their effectiveness in increasing the sales of EVs. The remainder of the paper is organized as follows. Section 3.2 describes the literature on state-level policies on EVs and their impacts on technology adoption and environmental outcomes. Section 3.3 identifies the two research questions. The following two sections analyze the evolution and emergence of EV policies, trends over time, across agencies and states, and the effectiveness of policies in increasing sales. Section 3.6 summarizes the findings and results, followed by conclusions in Section 3.7.

3.2 Incentives and policies: A review of the literature

3.2.1 Theoretical Frameworks in Energy and Environment Policy Adoption

Policy diffusion literature emerged as a mechanism for testing the adoption of innovative policies across state and local governments in the US. Some of the early research includes studies by Walker (1969) on several policy areas, followed by the work on adoption of lotteries by states (F.S. Berry and Berry 1990); the more recent works summarize of use of policy diffusion research across different program and policy arenas (Shipan and Volden 2012; F.S. Berry and Berry 2018). The policy diffusion literature in the energy and environment field predominantly focuses on implementing diffusion theories to explore inter-country, and inter- and intra-state influence in the adoption of renewable energy and energy efficiency policies (Matisoff 2008; Carley, Nicholson-Crotty, and Miller 2017; Matisoff and Edwards 2014; Zhou et al. 2019).

However, these studies focus on analyzing the determinants of policy adoption but do not explore the policymakers' preference of one versus another policy or the effectiveness of the policies themselves. For instance, we have evidence on the diffusion of renewable portfolio standards (RPS) across states; however, we do not know how the RPS gets selected over other clean energy policies, nor do we know if these policies are effective in contributing to higher EV sales.

The Multiple Streams Framework (MSF) provides a lens for looking at policy design choices. MSF has its roots in the agenda-setting literature pioneered by Kingdon (1984), which in turn builds on the Garbage Can model by Cohen, March, and Olsen (1972). Zahariadis (2014) provides a more updated version of the MSF– defining the three streams of problem, policy, and politics; and then exploring how policy ideas/solutions get adopted as policy windows get opened. The framework applies the idea of three parallel streams of policy, problem, and politics interacting to open policy windows where agendas get adopted, and policies get implemented. MSF has the unique characteristic of offering a structured yet flexible approach to explore policy processes.

Studies apply MSF to understand the adoption of different energy and environment related policies to examine the response to climate change, emissions trading, adoption of wind technologies and even in the space of EV policy adoption (Kern and Rogge 2018; Pralle 2009;

Brunner 2008; Yusuf et al. 2016). Normann (2015) finds that even when politics and problem stream combined when the window of opportunity opened for offshore wind in Norway, the absence of a fully developed solution (i.e. policy) led to a missed chance for adopting the technology.

In the context of EV policy, California first chose EVs as a solution for local air pollution in the 1980s and passed a low emission vehicle mandate. This represented an example of technology forcing (Calef and Goble 2007; Szarka 2012; Collantes and Sperling 2008). Despite the policy response at the time, available technology was not ripe enough for the market to take-off, and the policy goals had to be shifted to more than a decade later when affordable EVs were available in the market. Calef and Goble (2007) use policy styles to examine and contrast the adoption of EVs in California and France. They find that the aggressive and perhaps even adversarial approach followed in California was more influential in spurring the growth of low and zero-emissions vehicles as compared to the French case where the policy adoption process was smooth. Collantes and Sperling (2008) note the interrelatedness of the three streams - problems, politics, and policy in their analysis of EV policy in California. The existence of the problem stream (air quality) led to the evolution of the politics stream.

Despite this expanded coverage of policy adoption, MSF stops short of providing a way of analyzing the effectiveness of policies and comparing different policy options. Further, although the framework is easily adaptable, it does not provide any testable hypotheses and falls short of predicting policies or their outcomes (Cairney and Jones 2016; Kern and Rogge 2018). The following section looks at the policy analytical approaches in literature to address this gap.

3.2.2 Effectiveness in Energy and Environment Policy Tools

The literature on policies for addressing environmental externalities and market failures exists within the broader context of the tax benefits and financial incentives to nudge behavioral changes and instrument choice (Batchelder, Goldberg Jr, and Orzag 2006; Pitts and Wittenbach 1981; Jaffe, Newell, and Stavins 2005; Stavins 1996, 2003; Brown 2001). Studies examine energy tax credits for housing improvements (Walsh 1989), increasing energy efficiency and the effect of market failures and barriers (Brown 2001), the role of indirect network effects in electric vehicles (Li et al. 2017), production and investment tax credits for renewable electricity and biofuels (Murray et al. 2014), tax incentives for installing wind energy (Bird et al. 2005; J.I. Lewis and Wiser 2007) and support for alternative fuel vehicle credits (CBO 2012). A large body of research focuses on the adoption of state renewable portfolio standards (see, for example, Carley (2011); (Matisoff 2008; Rabe 2006)). Using state-level panel data in the electricity sector Carley (2009) examines the effectiveness of renewable portfolio standards; she concludes that while the adoption of RPS is not a significant predictor of the share of renewable energy in the generation mix, these standards are positively related to total renewable energy deployment over time.

Findings on the effectiveness of financial incentives and instruments for reducing the environmental impact of economic activity are mixed. Walsh (1989) uses a utility-maximizing model along with regression analysis to estimate the effects of state and federal tax credits on energy-saving investments by households. The findings suggest that there is no evidence of improvement in energy conservation as a result of the tax credits. On the other hand, Hassett and Metcalf (1995) leveraged state-level variation in-laws and found that after controlling for fixed effects, energy tax credit programs do lead to an increase in households' probability of investing in upgrades.

Specific to the transportation sector, in an ex-ante analysis of the federal tax credits for alternative fuel vehicles, the Congressional Budget Office (CBO) concluded that the current federal tax credits (estimated to cost around USD 2 billion) are not enough to make a typical EV cost-competitive with traditional internal combustion vehicles resulting in less than optimal investments in EVs (CBO 2012). On the other hand, while Li et al. (2017) find the federal income tax credit of $7,500 did contribute to an increase in sales of vehicles, they also state that investing the money in expanding the charging infrastructure would have been a more effective strategy. Murray et al. (2014) find that the Biofuel Tax credits provided by the federal government increased emissions. The authors use the National Energy Modeling System to conclude that removing the Volumetric Ethanol Excise Tax Credit (VEETC) would reduce GHG emissions by over 4 MMT CO_2e due to the changing land-use and an increase in the share of imported biofuels which have a lower emissions factor compared to the domestic blends.

Gallagher and Muehlegger (2011) assess the role of different incentives in the adoption of hybrid vehicles across different cities in the US. They find that the type of incentive offered at the state-level plays a role in increasing the uptake of these vehicles. In particular, sales tax waivers lead to a significant increase in the adoption of hybrids. Yang et al. (2016) identify essential incentive design practices that help in ensuring the maximum uptake of EVs across different markets. These include providing the benefits up-front, making incentives durable to maintain continuity for both manufacturers and consumers, making the value clear, and making the incentives available to the full target market. Sierzchula et al. (2014) examine EV policies across countries in 2012 and find that providing financial incentives can indeed be related to higher sales. Charging infrastructure also plays a significant role in EV sales. More recently, the Greenlink Group (2017) has studied the impact of reintroducing the income tax credit on EVs in Georgia.

The report reveals significant benefits in the form of GDP contributions and the number of jobs generated in the state's economy.

Amsterdam Round Tables and McKinsey & Company (2014), in the report titled "Electric vehicles in Europe: gearing up for a new phase?" enumerate several innovative business models to increase the share of EVs and integrating them into the grid. The report identifies three specific ideas for power distribution and delivery. These are smart grid applications, aggregating demand-side response and monetizing flexibility, and stationary storage using EV batteries. Rocky Mountain Institute's report on EVs distinguishes between two types of services that these vehicles could provide – V1G and V2G. V1G refers to managed- and smart-charging of EVs; V2G (vehicle-to-grid) uses EVs as power generators by supplying power back to the grid during periods of high demand and provides frequency and voltage regulation (Fitzgerald, Nelder, and Newcomb 2016).

While the evidence of policy effectiveness in increasing sales of EVs is consistent across studies, this is not true for the environmental effects of these policies. The evidence on environmental benefits of economic incentives on EVs is not conclusive. Holland et al. (2015) find that environmental benefits can vary a lot and further, that the environmental externalities from emissions are often just transferred from one state to another. Berestenau & Li (2011) find that in the period between 1999 and 2006, gas price increase and federal income tax incentives both explain higher HEV sales across 22 metropolitan statistical areas in the US. However, the authors question the efficiency of the subsidy stating that a flat rebate scheme would yield better results. Chandra, Gulati, and Kandlikar (2010) find that in some cases, economic incentives, while effective, also subsidize those consumers who would have purchased EVs in any case. As a result, the effective cost of avoided carbon emissions is $195 per tonne.

3.2.3 Gaps in Literature

Extant studies provide an analysis of incentive mechanisms and support policies, they often combine different types of EVs (often plug-in hybrids and battery only EVs). Further, these studies do not examine the heterogeneity in policies and their evolution over time. This provides limited guidance on the paths that policies have taken over time and their effectiveness in leading to higher sales of EVs and technology adoption. The theoretical framing of energy and environment policy focuses on applying the policy diffusion framework across states. While this framing of policy adoption has been insightful to determine which tools and instruments might get adopted by state and local governments, it stops short of providing any results on which tools might be effective. This literature also does not examine the effect of the agency, providing the incentives. This paper aims to address this gap. This paper aims to fill this gap by first empirically examining the trends in policy instrument choice across the sub-national governments; and then analyzing how this heterogeneity of policy responses and providers affects outcomes through sales of EVs at the state level.

3.3 Research Questions

This paper aims to address the gaps identified in the literature through two specific questions. The first focuses on the changing trends in policies to examine the evolving landscape.

What are the patterns and trends in the emergence and evolution of EV policies?

The associated hypothesis aims to test the relation and impact of EVs on complementary markets, i.e. electricity. Such multiple policies drive from the idea of policy-mixes affording the technology a high-leverage status (Skerlos and Winebrake 2010; Kern, Rogge, and Howlett 2019)

Hypothesis 1: As the market evolves, private participants (i.e. utilities) will play a more significant role in providing incentives

The second question focuses more specifically on the effectiveness of these policies at the state level.

How effective are the policies in contributing to the sales of EVs?

And, the two hypotheses the paper aims to test here are:

Hypothesis 2a: Policies to support EV sales are a significant driver of sales

Hypothesis 2b: There is a difference in the effectiveness of different policy measures in contributing to sales

3.4 Electric Vehicle Policy Landscape

The policies may apply to more than just electric vehicles, but for this study, I include all state and local level policies that address EVs.

3.4.1 Data

The Department of Energy's (DOE) Alternative Fuels Data Center (AFDC) publishes data on Alternative Fuel policies (AFDC 2019). The policy dataset provides a brief title, explanatory text, policy type, classifying characteristics, and key dates for the policies. The enactment dates are not reported for many policies. Typically, these are policies that got adopted without an act of legislation, and it is, therefore, difficult to estimate a date for them. However, in a Technical

Response from the Vehicle Technologies Office (VTO), I obtained an updated dataset where the consultants (ICF) provide estimated dates of enactment for several of these policies. The dataset also provides information on the types of technology associated with the law/legislation. One of the reported categories is "ELEC" defined as "All-Electric Vehicles."[4] This paper focuses on policies that mention ELEC as one of the technologies. The following sections analyze the state and local policies, identify patterns and trends, and provide some key observations on the nature and coverage of policy response.

3.4.2 Description of the EV policy landscape

Before examining the trend in the types of policies and their evolution over time, it is pertinent to examine their different types and categories. Broadly, the alternative fuel policies can be categorized into five groups – incentives, programs, state incentives, utility incentives, and laws

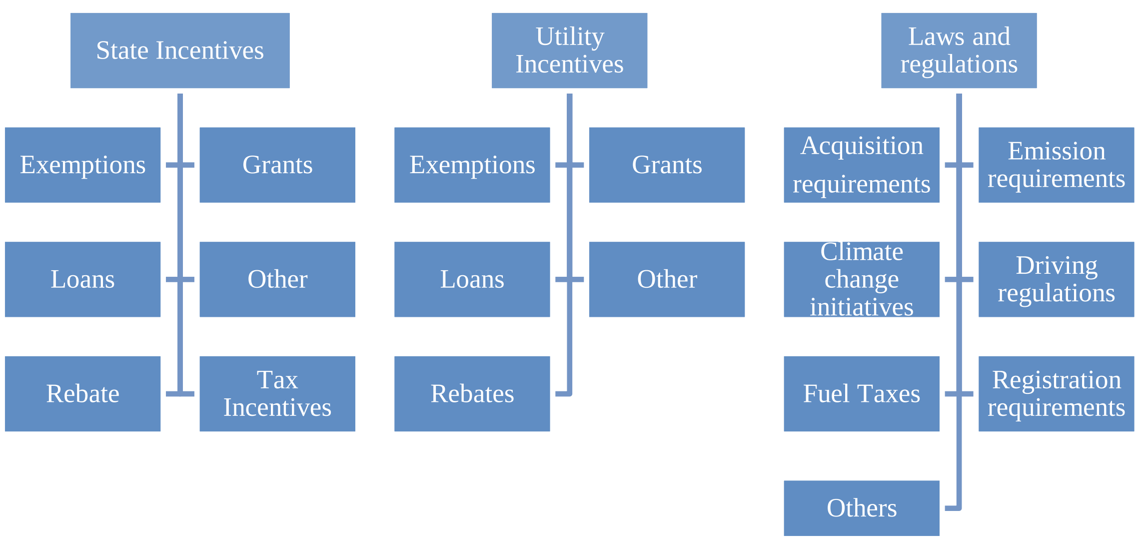


Figure 3-1: Sub-types within state and utility incentives and regulations

[4] It is important to note here that a policy may be applicable to more than one vehicle category y

and regulations. The first two (i.e., incentives and programs) are at the federal level and include policies such as infrastructure incentives and the clean cities coalition network.

In addition, the federal government enacts laws and regulations that further allow states to provide benefits to alternative fuel vehicles. These include permitting high occupancy vehicle lane access, usage of alternative fuel vehicles for state and federal government fleet vehicles, etc. However, the analysis does not include these federal-level policies as the focus here is to examine trends and effectiveness of state policies. Incentives (both at the state and utility levels) and laws and regulations can further be categorized into different types (Figure 3-1). Within utility and state incentives, policy tools include tax credits and exemptions, grants, loans, and rebates. Laws and regulations can be classified into acquisition, emission and registration requirements, climate change initiatives, fuel taxes, and other regulations.

3.4.3 Results: Evolution of policy-types over time

Laws and regulations have dominated the policy basket for electric vehicles across time (Figure 3-2). The policies have increases in number as well as complexity over time. The policies introduced in the 1990s focused on setting standards and approval procedures for alternative fuel vehicles (AFVs). Several of these regulations were introduced in response to the Energy Policy Act passed by the federal government in 1992. Further, these policies were typically combined for different new technology initiatives. The intensity and coverage of policies have evolved from addressing alternative fuel vehicles (AFVs) in general to more specific designs that address components of the evolving EV sector. Thereafter, in the 2000s, incentives to support alternative transportation modes included tax credits, rebates, and infrastructure grants (Figure 3-3). More recent laws relate to parking and charging infrastructure requirements, allocation of funding, and additional fees that EV owners are now required to pay.

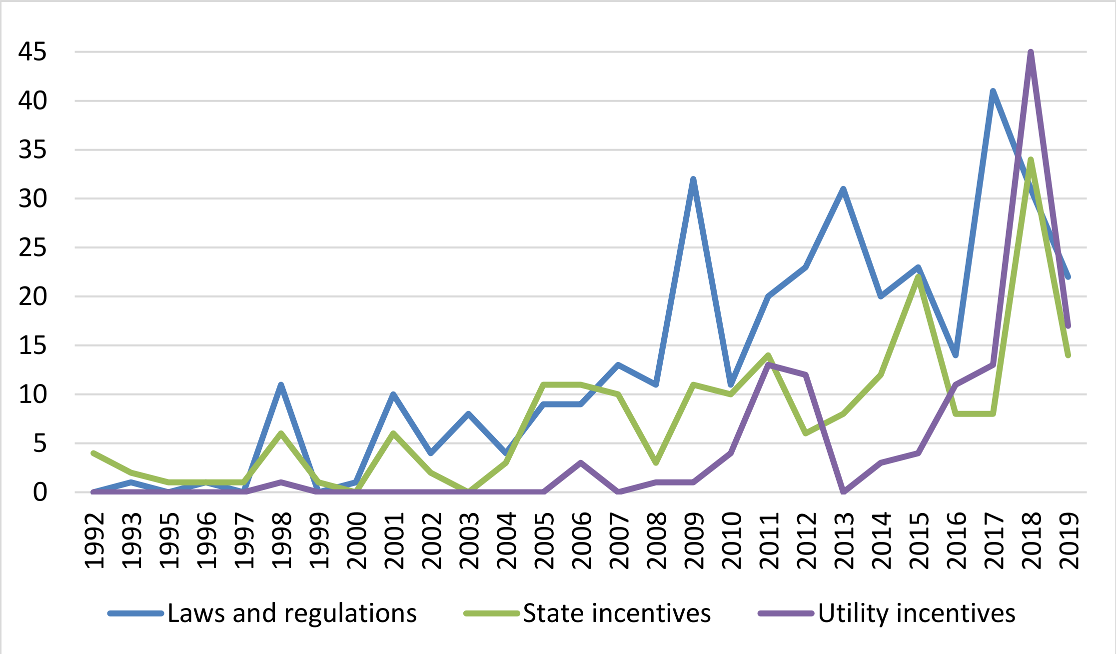
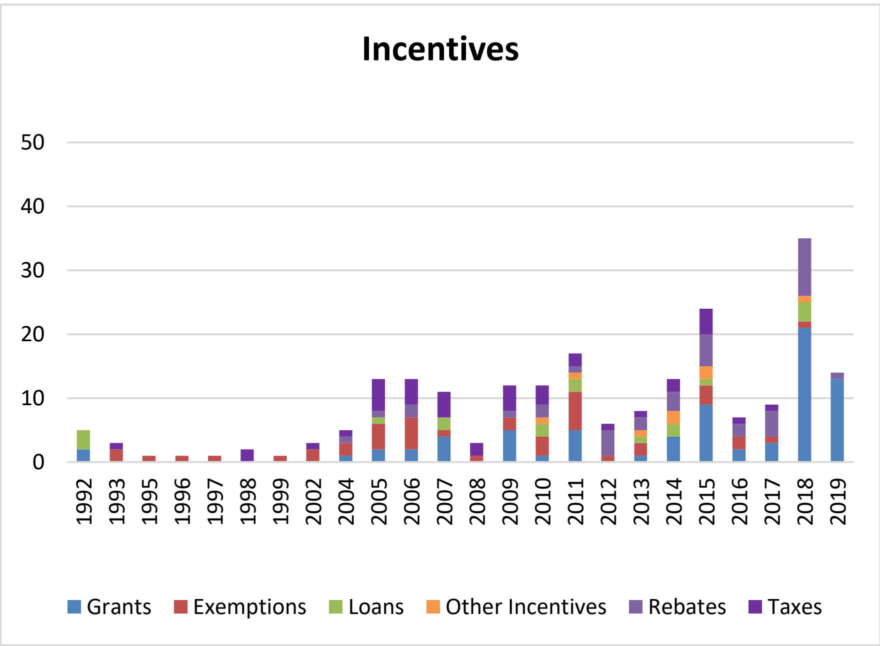


Figure 3-2: Adoption of different policy types over time



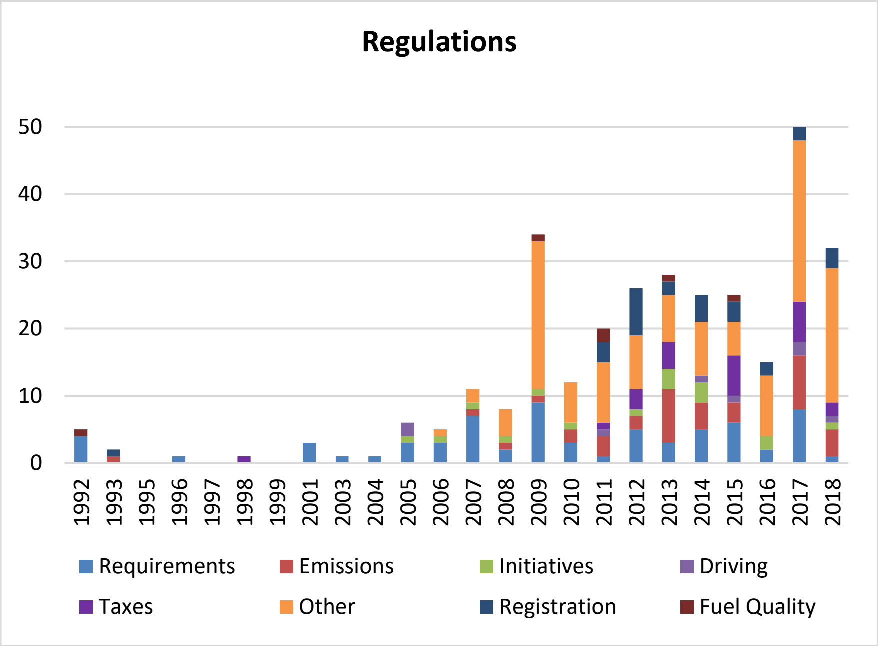


Figure 3-3: Distribution of State provided EV incentives and regulations over time

To examine the average duration of different types of policies provided by state and local governments, I run survival estimates (Kaplan and Meier 1958) to calculate the median tenure of the state-provided policies (Figure 3-4). The figure shows the share of policies and the number of years they remain in existence before being superseded or expiring. For example, looking at the blue line that represents laws and regulations, 50%, i.e., the median number of laws expire in just under five years; a quarter of the laws (where the share of policies is 0.25 on the vertical axis) expire in around seven years.

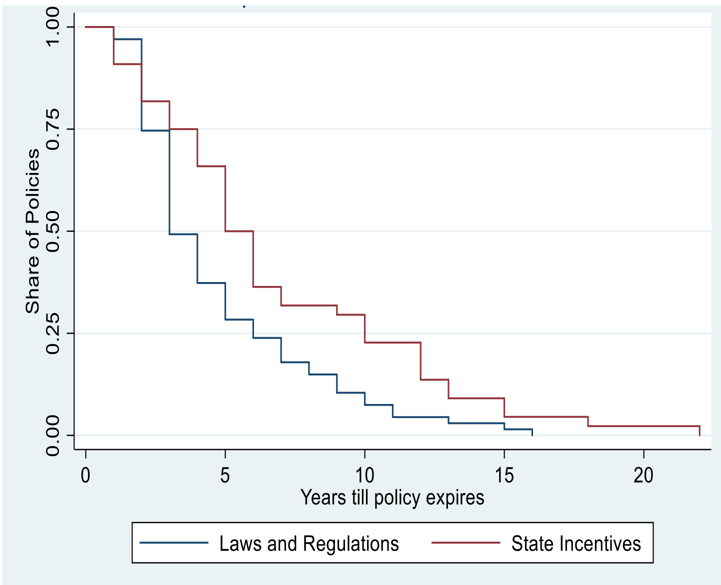


Figure 3-4: Kaplan Meier survival estimates of state incentives and regulations

Source: Data from AFDC (2019)

On average, incentives last longer than the regulations. The median length of laws and regulations relevant for EVs is less than five years, whereas that for incentives is closer to seven years. This difference in tenue of policies provides an interesting insight since even though financial incentives have explicit fiscal costs, they appear to last longer than regulations. Further, given prior research on the potential for leakage from financial and tax-based incentive instruments and the potential equity implications, it is interesting to note the difference in the policies' respective tenure. In addition to the general increase in policy activity over the decades, three factors emerge. First, the distribution of policies across states is worth noting, with some states being the clear front-runners in adopting policies to support this new technology. Second, examining the trend in sub-categories of incentives and regulations, states are rolling back tax incentives and introducing registration taxes to account for the losses in gas tax revenues. Third, the number of utility policies has increased with the private sector, responding to the growing market for electricity demanded from the rising numbers of EVs on the road.

3.4.4 Distribution of policies across states

States vary in the number and frequency of policies introduced over time (Figure 3-5). With a total of more than 100 policies in the reporting period, California has issued the most significant number of legislations to-date.

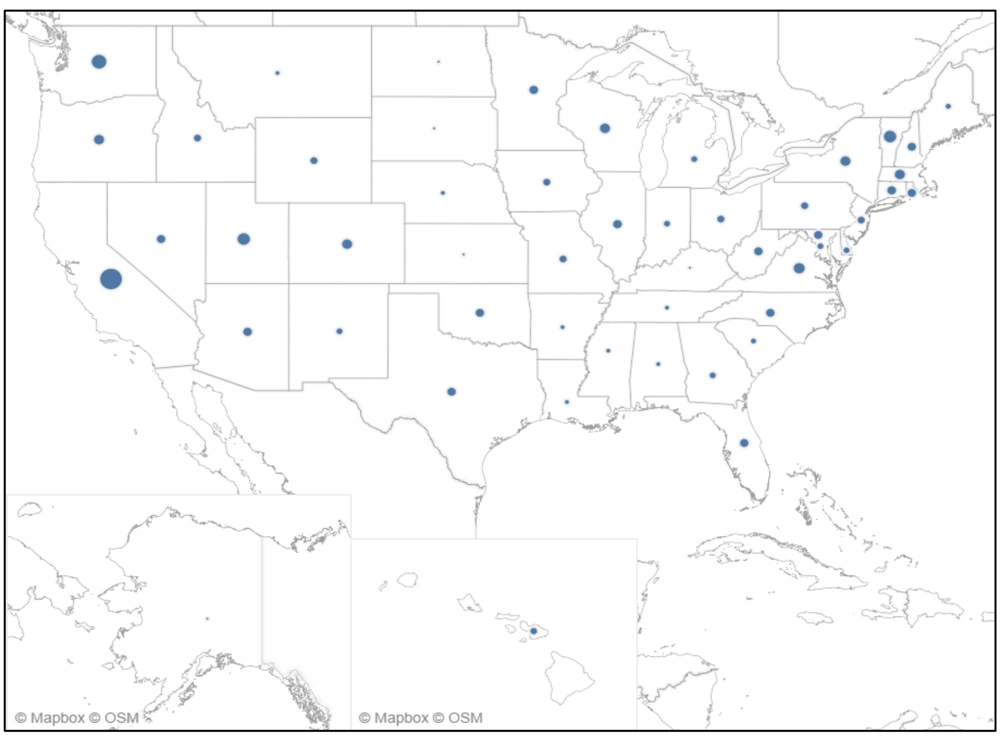


Figure 3-5: EV Policies in 2018 across the states

Washington and New York follow with 35 and 34 policies in place, respectively. Over time, states are introducing incentives as well as regulations to address the market. This distribution is reflected in the HH Index calculated over time which has decreased from 0.37 in 1992, the start of the dataset to 0.09 in 2018.[5] Another interesting insight that this map provides is the apparent lack of any spatial spread of policies. Policies to support EVs seem to be spread out across states, particularly in the coastal states in both – the east and west coasts.

3.4.5 *Utility incentives*

In addition to state-level incentives, the number of utility level incentives have increased in both coverage and numbers (Figure 3-6). The first set being introduced in California in 2006, followed by several other states in 2011. Several of these are at the city and county levels, the typical operational level for most electric utilities. Most of the utilities provide infrastructure support for charging (e.g., Georgia Power), electricity rate reduction for households with EVs

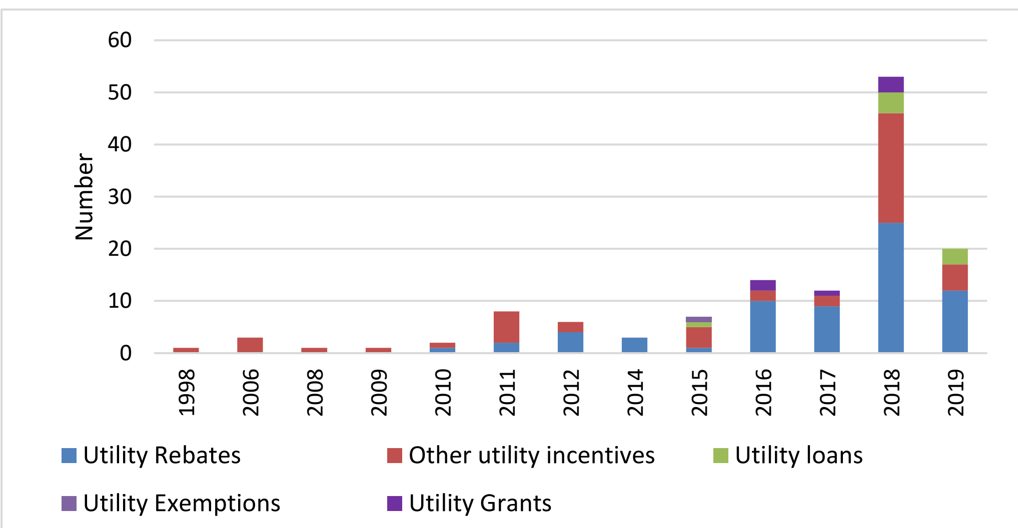


Figure 3-6: Distribution of utility incentive types

[5] This excludes certain years where only one state passed a policy, yielding an HH Index of 1.

(LADWP in California), rebates on EV purchases by utility customers and employees (KCP&L customers in Kansas), and conducting pilot programs (Duke Energy in Indiana).

3.4.6 The shift from tax incentives to registration taxes

Wisconsin was one of the first states to introduce a tax incentive in 1993. As noted earlier, in recent years, states have rolled back tax-related incentives for EVs and in place introduced additional fuel taxes and fees for these vehicles (Figure 3-7). The potential inadvertent adverse effects of higher EV sales have affected state finances and led to a reassessment of these incentives. The feedback from consumers and market response has led to policy repurposing. For example, in 2015, Georgia rolled back a $5,000 tax credit on EVs and imposed an annual plug-in electric vehicle fee of over $200,[6] which would increase annually. Some state governments are re-evaluating and changing their incentive designs while others are maintaining and even strengthening their support, and yet others have not even considered adopting these mechanisms.

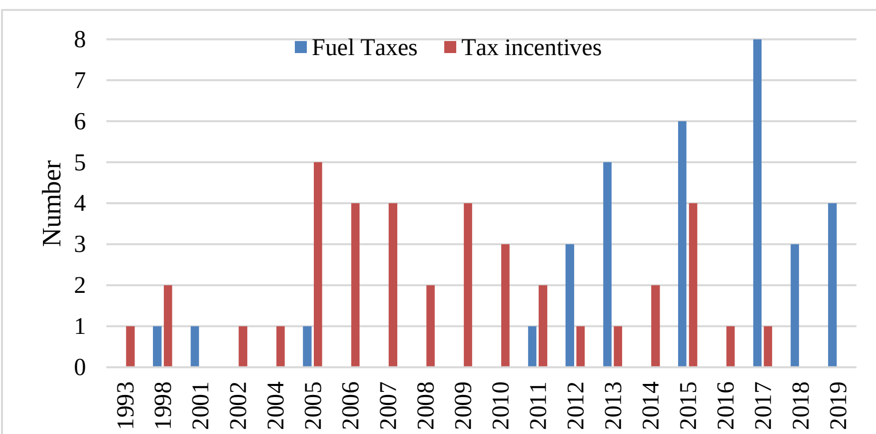


Figure 3-7: Fuel taxes and tax incentives

[6] The fee currently stands at $212.78 for non-commercial motor vehicles and $319.27 for commercial vehicles (DOR 2019) .

3.5 Effectiveness of Policy Instruments

The next step is to examine the effectiveness of policy choice and instruments in influencing consumer behavior. That is, do these policies lead to better outcomes in terms of higher sales of vehicles? To answer the question on policy effectiveness, the paper uses a panel dataset created by combining sales of EVs with the policy database described in Section 3.4. Table 3-1 summarizes the variables and sources of data in the analysis.

Table 3-1: Variables and data sources

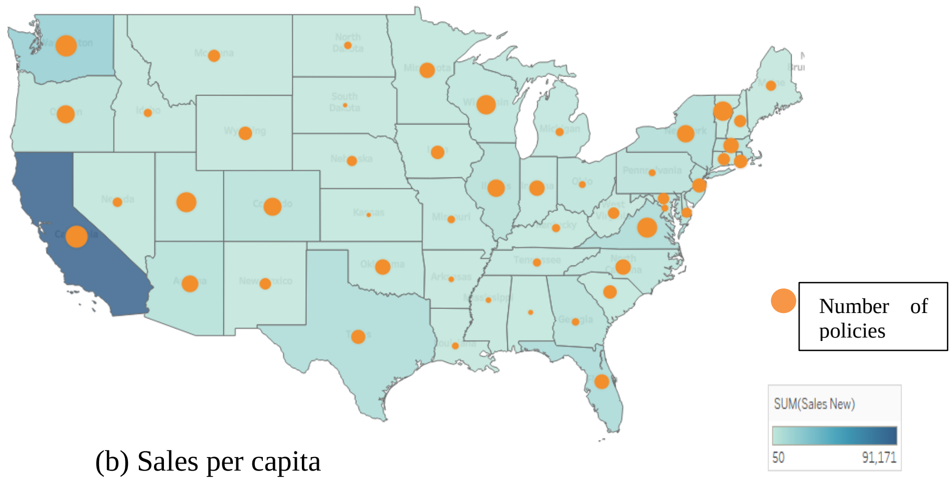
Variables	Source	Years
Sales of EVs	Auto Alliance Dashboard	2011- 2018
Share of EVs in total car sales	Auto Alliance Dashboard	2011- 2018
Electric Vehicle Policies	Alternative Fuels Data Center (Department of Energy)	n.d. – 2019
State Population	US Census Bureau	2010-2018
Ideology	State government ideology data by W.D. Berry et al. (1998)	2011-2017
GDP (in $’000)	Bureau of Economic Analysis	2011-2018
Price of electricity	Energy Information Administration (Department of Energy)	2011-2017
Price of gasoline	Energy Information Administration (Department of Energy)	2011-2017

3.5.1 Variables

EV Sales Data: Perhaps one of the most significant constraints of a study such as this is the availability of vehicle sales data. Several prior studies have relied on proprietary data provided by IHS Markit. However, starting in 2011, the Auto Alliance has reported sales of alternative fuel vehicles (including EVs) on its Advanced Technology Vehicle Sales Dashboard (Alliance of Automoible Manufacturers 2019).[7] The Auto Alliance reports data through a graphical dashboard for each state. Using this Dashboard, I manually enter the data series, limiting the dataset to annual retail sales of battery electric vehicles (BEV) only. Some interesting trends are revealed. First, sales in California are disproportionately higher than the rest of the country (Figure 3-8 (a)) However, once the sales are normalized by the population, we find that Washington had the highest sales per capita, followed by California. Some other trends emerge upon standardization by population. For instance, Vermont and Georgia reflect comparable sales per million residents. Further, Washington, Texas, and Florida witness some of the most substantial increases in EV sales over the period under analysis (Figure 3-9). Georgia also reveals a compelling case where the sales dropped drastically after 2015 once the state tax credits expired.

[7] https://autoalliance.org/energy-environment/advanced-technology-vehicle-sales-dashboard/, last accessed September 7, 2018.

(a) Total Sales



(b) Sales per capita

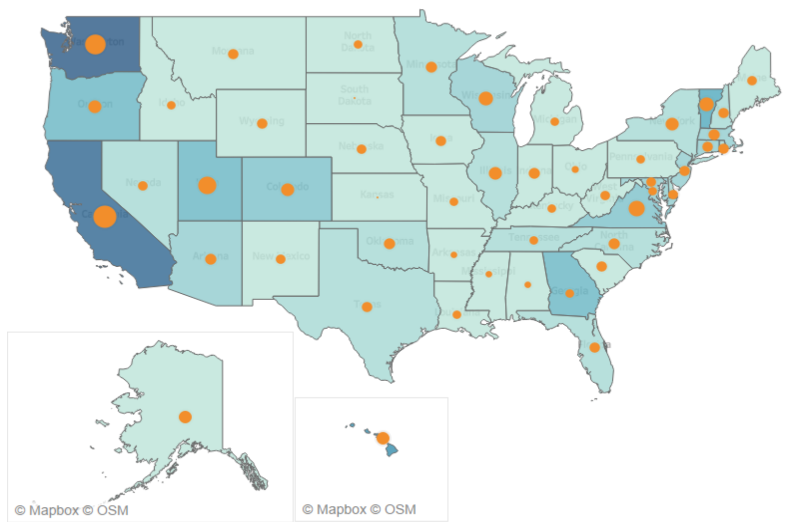


Figure 3-8: Total Policies and sales of EVs in 2018

Figure 3-9: Sales by state over time

Source: Auto Alliance Dashboard
Note: California is not included in this panel due to the significant scale difference (the sales of EVs increase from 5,062 in 2011 to 91,171 in 2018)

State Population: Population data is obtained from the Census Bureau. The Table is titled Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2010 to July 1, 2018.

Ideology: To account for the role of government and citizen ideology in policy adoption, I incorporate these variables in the model. I use the updated version of ideology data provided by (W.D. Berry et al. 1998). The authors provide two estimates – Citizen Ideology, and Government Ideology. I include government ideology in the final model, for two reasons – first, the data is available for the entire period (i.e., 2011-2017); and second, the decision to adopt EV policies is usually taken at the level of government; more liberal states are likely to see a more considerable uptake of EVs.

GDP per capita: Richer states are more likely to have a larger share of EVs due to the residents' affluence. In order to control for this, the model includes the per capita gross domestic product for the states.

Price of gasoline and electricity: The Energy Information Administration's (EIA) State Energy Data System (SEDS) provides the data on energy prices. Since prices in the SEDS database are reported as $/MMBtu, I use the conversion factors provided by the EIA to convert the gas prices to $/gallon, and electricity prices to $/kWh.

3.5.2 Model Specification

I run three main specifications for the model – the first examines the intensity of policy measured by the total count of policies to support EVs adopted in the state. The hypothesis here is that a **higher number of policies** shows a state's commitment to encouraging EV adoption and should therefore lead to an increase in sales. In the second model, I explore the Incentives and

Regulations separately to analyze which design components relate to the largest change in EV sales. Finally, to address the varying population sizes across the states, in the third model, I examine the density of EVs by introducing a dependent variable that normalizes sales by per million residents. The first equation is:

$$EVSales_{i,t} = f(Policies\#_{i,t}, GDP_{i,t}, Government\ ideology_{i,t}, Electricity\ Prices_{i,t}, Gas\ Prices_{i,t})$$

Where *i* represents the state, and *t* is the year from 2011 to 2017.

The second equation uses a different dependent variable:

$$EVShare_{i,t} = f(Policies\#_{i,t}, GDP_{i,t}, Government\ ideology_{i,t}, Electricity\ Prices_{i,t}, Gas\ Prices_{i,t})$$

Where *i* represents the state, and *t* is the year from 2013 to 2017.

The third equation uses density of EV sales as the independent variable:

$$EVSales_{i,t} = f(Policies\#_{i,t}, GDP_{i,t}, Government\ ideology_{i,t}, Electricity\ Prices_{i,t}, Gas\ Prices_{i,t})$$

Where *i* represents the state, and *t* is the year from 2011 to 2017.

3.5.3 Model Results

The results of the three regressions are presented in

Table 3-2. The number of policies in a state is significantly related to the sales of EVs and the share of EVs in total car sales. Since the first model is log-linear, we interpret the independent variable as a percentage - each additional policy is related to a 5% increase in sales. However, the coefficient is significant at the 5% and not 1% level. In the second model, we conclude that an additional policy increases the share of EVs in total sales by 0.03% points. Finally, in the third column, each additional policy increases EV sales by over 22 Cars per million population.

Table 3-2: Model Results

	Log(EV Sales)	Share of EVs in Car Sales	Sales of EVs per million population
Cumulative number of Legislations/policies	0.048**	0.034***	22.291***
	(0.021)	(0.011)	(5.719)
Per capita GDP (in $'000)	-0.076***	0.004	-0.133
	(0.027)	(0.014)	(0.681)
Gas Price $/gallon	-0.963	0.156	8.793
	(0.595)	(0.141)	(5.503)
Electricity price c/kWh	0.046*	0.006	257.288***
	(0.027)	(0.005)	(82.945)
State Government Ideology	0.003	-0.001	-18.278***
	(0.005)	(0.001)	(5.030)
Observations	346	250	350
R-squared	0.817	0.291	0.531
Time Fixed effects	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

The next set of analyses look at the difference between state incentives and laws and regulations (Table 3-3). In the first model, an additional incentive increases sales by 20%, whereas laws and regulations are not significant. In the second model, an additional incentive increases the share of EVs in total car sales by 0.1% points. Laws and regulations are also significantly related to shares of EVs in total car sales, and each new law/regulation increases sales by 0.02% points. In the third column, an increase in financial incentives and regulations supporting the EVs are both positively related to EV density. Additionally, in the last specification that tests the density of EVs by population, fuel prices are also significant. A dollar increase in gas prices is related to the sale of 256 more EVs per million population, and one cent per kWh increase in electricity prices decreases the sales of EVs by 20 per million population.

Table 3-3: Model Results: State Incentives vs. Laws and Regulations

VARIABLES	Log(EV Sales)	Share of EVs in total car sales	Sales of EVs per million population
Number of State Incentives	0.201***	0.099**	35.525**
	(0.072)	(0.045)	(17.199)
Number of Laws and Regulations	0.001	0.024***	26.512***
	(0.031)	(0.008)	(5.962)
State Government Ideology	0.001	-0.002	-0.499
	(0.005)	(0.002)	(0.745)
Gas Price $/Gallon	-0.606	0.200	256.350***
	(0.554)	(0.125)	(61.936)
Electricity price c/kWh	0.044	0.004	-19.975***
	(0.027)	(0.005)	(5.418)
Per capita GDP (in $'000)	-0.075**	0.000	6.107
	(0.029)	(0.015)	(4.276)
Constant	7.531***	-0.709	-1,082.527***
	(2.146)	(1.010)	(343.255)
Observations	346	250	350
R-squared	0.824	0.366	0.567
State Fixed Effects	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Next, in the third set of analyses, I explore the role of public versus private/quasi-private provision of incentives (Table 3-4). While the sales of EVs seem to be more responsive to utility incentives, the share of EVs in total car sales increases more with an additional state-provided incentive. However, the values are not very different from each other. The two incentive sources do not vary much in their overall effectiveness. Further, the F-test among the two coefficients was also insignificant, indicating that the sales for utility-provided and state-provided incentives are not significantly different from each other. However, in the final model, the utility provided incentives do not appear to affect the density of EVs when we account for the population size, whereas the state provided incentives are significantly and positively related to sales. Each additional state incentive policy increases the sales of EVs by 36 vehicles per million population.

Table 3-4: State vs. utility provision of incentives

VARIABLES	Log(EV Sales)	Share of EVs in total car sales (%)	Sales of EVs per million population
Number of State Incentives	0.146***	0.074**	36.301**
	(0.047)	(0.035)	(13.905)
Number of Utility Incentives	0.168***	0.063**	14.428
	(0.058)	(0.028)	(11.148)
State Government Ideology	0.004	-0.000	0.168
	(0.005)	(0.001)	(0.594)
Gas Price $/Gallon	-0.617	0.261*	363.629**
	(0.590)	(0.140)	(150.454)
Electricity price c/kWh	0.041	0.012*	-10.944
	(0.026)	(0.007)	(9.753)
Per capita GDP (in $'000)	-0.067**	0.006	14.951*
	(0.026)	(0.016)	(8.515)
Constant	6.729***	-1.400	-2,009.082**
	(2.146)	(1.154)	(931.627)
Observations	346	250	350
R-squared	0.826	0.322	0.459
State Fixed Effects	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Finally, comparing across all policy types, we find that state incentives are a significant driver of EV sales, share of EVs in total sales, and the density of EVs by population, at varying levels of significance. Further, while utility-based incentives are significant in the first and second models, i.e., the percentage increase in EV sales and share of EVs in total car sales, these privately provided incentives are not significant when we account for the varying levels of population. Finally, looking at laws and regulation based policies, they are significant when the dependent variables are the share of EVs and the density of cars – each addition law increases the share of EVs in total car sales by 0.02% points and the number of EVs by 26 cars per million population. Further, another notable outcome in the last specification is he relation between fuel prices and EV adoption. Increase in gas prices are strongly and positively related, and the prices of electricity are inversely related to the density of EVs.

Table 3-5: Comparing all policy types

VARIABLES	Log(EV Sales)	Share of EVs in total car sales (%)	Sales of EVs per million population
Number of State Incentives	0.151***	0.065*	20.838*
	(0.046)	(0.036)	(11.919)
Number of Utility Incentives	0.167***	0.060**	14.986
	(0.058)	(0.025)	(10.887)
Number of Laws and Regulations	-0.009	0.019**	25.951***
	(0.026)	(0.009)	(7.572)
State Government Ideology, 1960-2017	0.004	-0.001	-0.060
	(0.005)	(0.001)	(0.696)
Gas Price $/Gallon	-0.574	0.230*	241.039***
	(0.585)	(0.118)	(64.145)
Electricity price c/kWh	0.044*	0.008	-18.714***
	(0.026)	(0.005)	(4.911)
Per capita GDP (in $'000)	-0.064**	0.003	8.023
	(0.027)	(0.015)	(4.840)
Constant	6.439***	-1.101	-1,178.930***
	(2.127)	(0.974)	(399.128)
Observations	346	250	350
R-squared	0.826	0.334	0.543
State Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Finally, to examine the effectiveness of specific policy tools, the next set of analyses test for specific incentives or regulations (Figure 3-10 - Figure 3-15). In the case of incentives, rebates are consistently significant in increasing EV sales and density. Additionally, grants- and loans-based incentives also become significant when we test for their effectiveness in increasing the density of EVs (Figure 3-11). In the case of laws and regulations, no consistent patterns hold across the different dependent variables. Driving related regulations are significant in the percentage of EVs sold (Figure 3-13), and emission and acquisition requirements are significant when testing for the share of EVs in total car sales and density of EVs by population (Figure 3-14 and Figure 3-15).

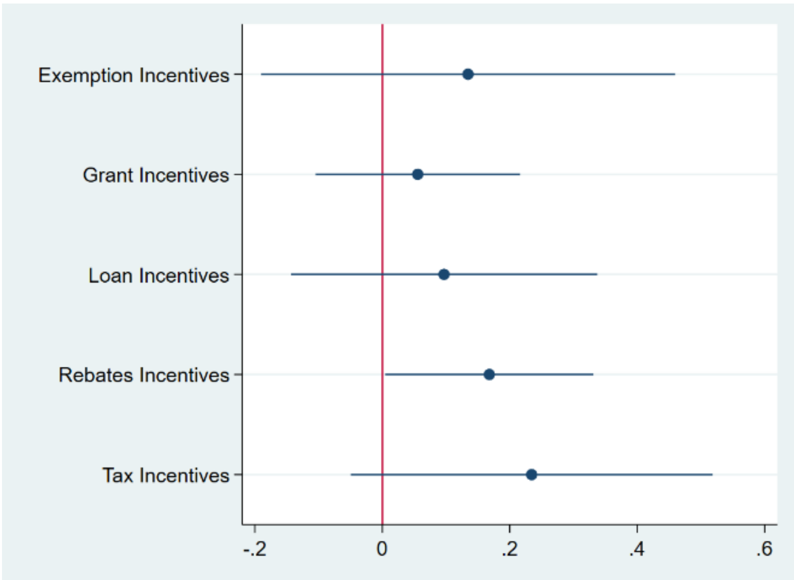


Figure 3-10: Impact of financial incentives on log(EV sales)

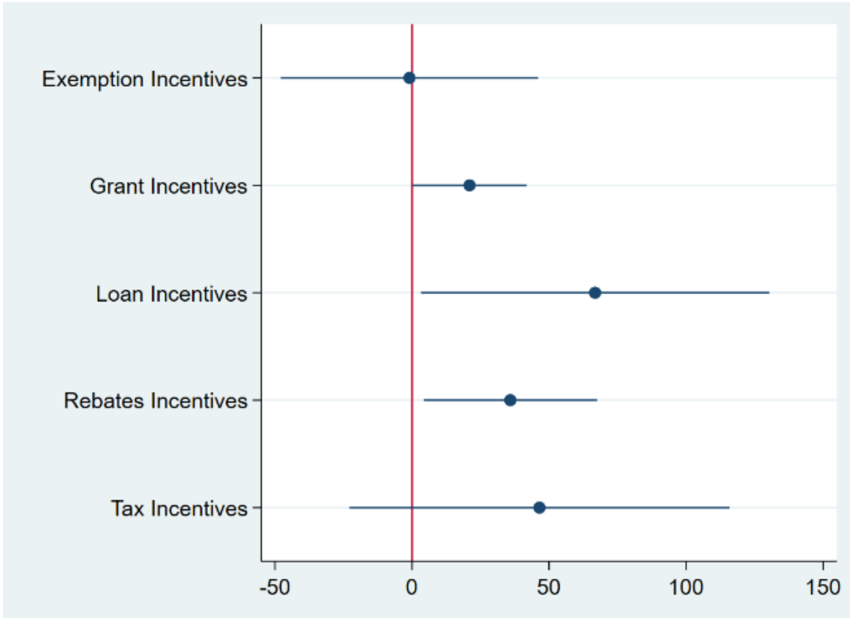


Figure 3-11: Impact of financial incentives on EV density by population

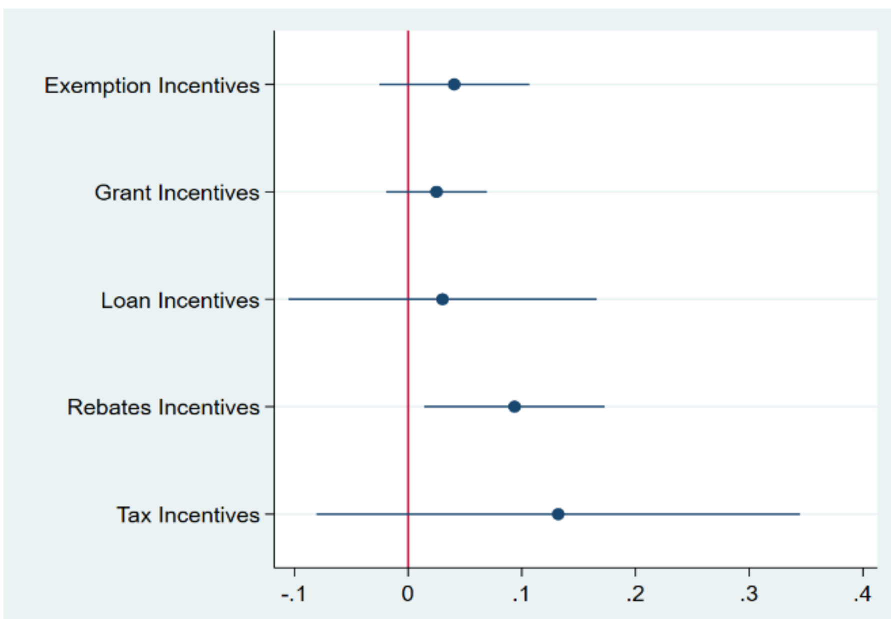


Figure 3-12: Impact of financial incentives on share of EVs in total car sales

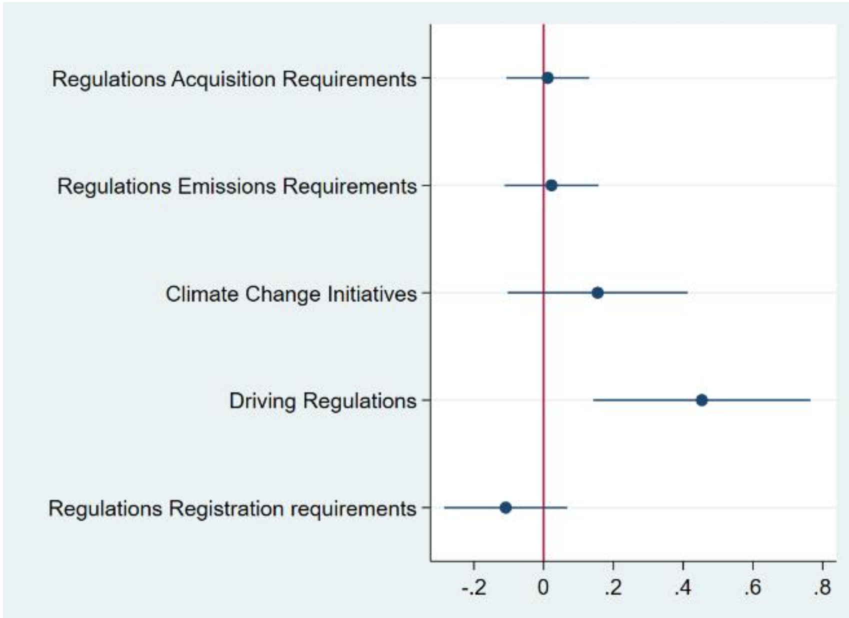


Figure 3-13: Impact of regulations on log(EV sales)

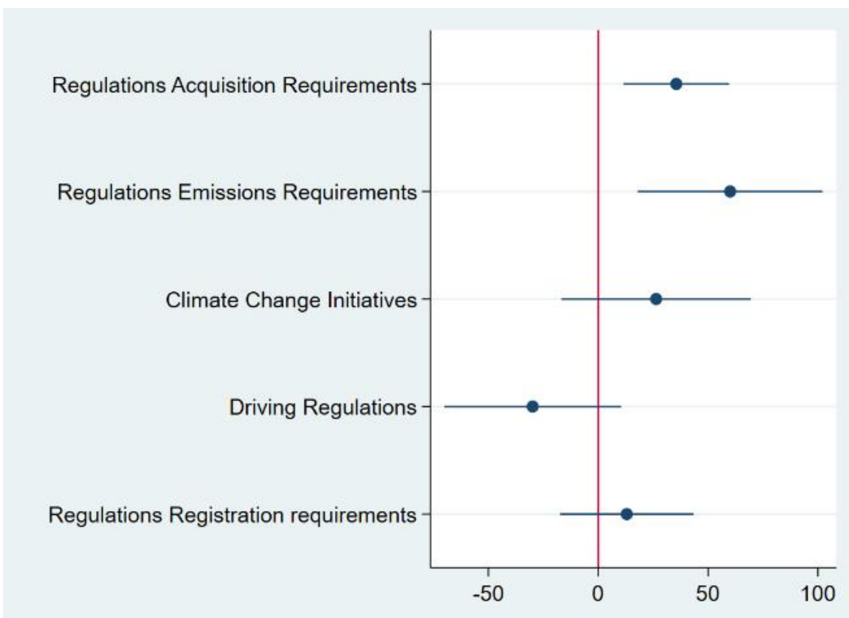


Figure 3-14: Impact of regulations on EV density by population

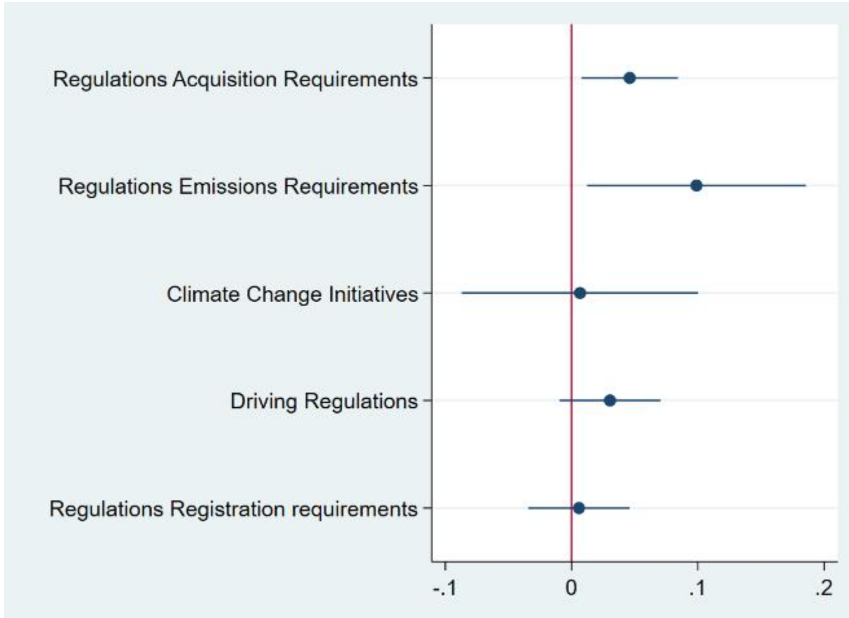


Figure 3-15: Impact of regulations on share of EVs in total car sales

3.6 Discussion

This paper summarizes several lessons from the evolution, adoption, and effectiveness of EV policy over time and across states. There are some key points to note here that provide evidence of policy learning. First, the breadth and depth of coverage of policies across states have increased. The technologies covered and the nature of policies have both evolved significantly since the early 1990s. States are deploying both carrots and sticks to support the EV sector. Carrots come in the form of financial incentives such as tax incentives and rebates; sticks comprise laws and regulations such as driving regulations and charging infrastructure provision. Even though the number of laws and regulations exceed incentives, on average, the financial incentives last longer than laws and regulations. Within this evolving policy system, state-level variation persists in both policies and sales of EVs. While most states have some incentive or regulation in place that directly targets EVs, a few states account for a disproportionate share of overall sales and policy activity.

While states deploy a combination of regulatory and incentive-based policies, the cumulative number of regulations outnumbers the incentives. In addition, with the realization that EVs provide a market for electricity, the private provision of incentives by utilities through rate reduction, discounts, and charging infrastructure is an emerging trend. Even though the vehicles themselves are private goods, they reduce local and global pollution, thereby reducing negative externalities and producing cleaner air, a public good.

In the analysis of the effectiveness of policies in contributing to sales of EVs, this paper finds that policies to support alternative fuel technology do work. However, there is variation in the overall effects of different types of policy instruments. Incentives also cause a financial burden to the state and local agencies, implying that policy design matters, and choosing the right tool plays an essential role in determining private and public outcomes. Finally, state and utility provided incentives are both effective in driving sales of EVs. Within the specific financial instruments, rebates are positively and significantly related to EV sales and density. In the case of laws and regulations, different tools are significant, depending on the measure of EV sales used.

This creates a role for the local managers to ensure that private and public incentives align and do not counteract each other. In addition, oversight in this area would also be necessary in order to ensure that benefits are distributed equitably. Further, as the local density of EVs increases, interventions to provide supporting infrastructure through regulations and grants will be necessary. Finally, in the age of increasing financial pressures on governments, there has also been a retraction in incentive policies where some states have entirely removed the incentives that they once provided, and others have made announcements to that effect. Additionally, states have introduced registration fees and taxes on EVs to account for the potentially declining revenues from gas taxes as the share of EVs increases.

3.7 Conclusions and future research

This paper looks at various aspects of the EV policy landscape across the US states. This area has gone through several iterations of evolving policies. States have adopted policies for myriad reasons ranging from meeting local environmental and air quality targets to supporting new industries and generating employment. States have introduced incentives, regulations, and other support mechanisms for alternative fuel vehicles such as EVs. Besides, electric power utilities also participate in this space as they see a growing demand for electricity from EV owners. Further, as utilities begin to realize other benefits from EVs through services such as frequency regulation, capacity addition, and demand response, the power sector might develop entirely new business and market models to monetize them (Brown and Soni 2019).

Instances of policy introduction, retraction, and repurposing provide lessons on different aspects of policy development, tool choice, public administration, and finance. The suite of tools adopted includes financial incentives as well as regulatory policies. Some of the tools and instruments in this space include rebates, tax incentives, building code requirements, and enhacing charging infrastructure in public buildings. These tools vary in their application, coverage, and effectiveness as measured by the percentage sales of EVs, the share of EVs in total car sales, and the density of EVs by population.

In addition to the policy design implications, this research also informs public managers regarding the tools they may have available and could deploy based on the level of maturity of the market. The introduction of registration fees on EVs also provides lessons on public finance – state and local governments often rely on revenues from the transportation sector through fuel taxes. A shift to an electric drive train is likely to affect the revenue source for states. Planning to ensure that alternative streams of revenue can supplement the dwindling tax revenues without adversely affecting the market for EVs would be valuable. Finally, another aspect of this space is the participation of utilities in generating and providing policies to support EV sales. While the motivating factor behind providing incentives for private and quasi-private utilities might be the potential increase in electricity sales, they generate positive externalities in the process and contribute to improved environmental outcomes.

A future step to extend this research would be to look at the financial implications of these policies – estimating the size of incentives and the impact on state and local government finances. Another dimension would be to analyze in greater detail, the relation between state and utility provided incentives – do these coexist or do utility incentives replace state incentives over time. Finally, as states redefine or retract policies, examining the impact of policy retrenchment on sales and businesses will help determine the implications of policy uncertainty and its implications on generating environmental and macroeconomic outcomes.

CHAPTER 4. VALUES, ACTIONS, AND OPINIONS FOR LOW-CARBON MOBILITY: ASSESSING PUBLIC SUPPORT FOR ELECTRIC VEHICLES IN THE NORDIC REGION

4.1 Introduction

The number of electric vehicles (EVs) has increased rapidly across the globe. Over the past five years, the total stock of EVs has increased from less than 50,000 in 2014 to over 3 million in 2018 (IEA 2018a) In keeping with other clean energy and smart grid policies (Zhou and Brown 2017), Nordic countries have been at the forefront of promoting electric mobility (IEA 2018b). Rising EV sales in Norway, which ranks as the global leader in market share with EVs comprising nearly 40% of new vehicle sales (EAFO 2018; IEA 2019). As in the case of the US, much of the growth in the EV market in the Nordic region is attributable to a supportive policy environment (Kester et al. 2018b, 2018a). The policy instruments adopted in the region include registration tax benefits and exemptions, investment in public charging infrastructure, parking incentives, and access to bus lanes at the sub-national level. While most of these incentives address the cost of owning and operating an EV, the consumer perception of EVs needs to be examined in greater detail.

Public perceptions play an important role in the widespread adoption of new products and services. This is particularly true of new technology (Huijts, Molin, and Steg 2012). Prices, ease of use, past experiences with the technology, the ability to test the technology (such as in a store, or at a vendor location), knowing people who have used or owned the technology determine the pace at which this new technology will diffuse. Even though EVs have been on the market for several decades, only the recent models have been able to attract the attention of a significant base of purchasers. As perceptions of these vehicles have evolved over time, so have the key drivers of public opinion. Until recently, the price of vehicles has been the key factor in determining perceptions (Axsen, Bailey, and Castro 2015). With recent and projected improvements in battery technology, cost reductions, and expanded driving range (IEA 2018a; BNEF 2018b), financial and technical barriers are less likely to be the biggest hindrances to the adoption of EVs. Social and cultural aspects of vehicle adoption will likely continue to influence the penetration of EVs. Further, as EVs become more visible, the user experience and the ability of EVs to support different lifestyles will likely play an important role in consumer decision making.

Deliberations about policy have occurred in tandem with advances in conceptual and analytical frameworks for EVs and electric mobility more broadly. Sovacool (2017) summarizes the prevalent theories in the context of EVs and proposes a unified framework highlighting four main characteristics that determine the choice of vehicles. These include motile pleasure, sociality, socio-material commensurability, and habitual momentum. Models of decision-making and consumer preferences have also proven valuable in explaining the adoption of "green" technologies (Sovacool 2017). Rezvani, Jansson, and Bodin (2015) identify four key areas that consumer choice literature on EVs draws from – planned behavior and rational choice; symbols, self-identity and lifestyle; diffusion of innovation and consumer innovativeness; and consumer emotions. Going beyond just EV research, another study identified fifty (!) theoretical approaches that have been used to explain environmental attitudes and consumer choices - 27 of these look at the beliefs, attitudes, and values of the decision-makers and the remaining 23 studies look at contextual factors and social norms (Brown and Sovacool 2018). However, despite the growing belief and understanding of climate change (G.B. Lewis, Palm, and Feng 2018; McCright, Dunlap, and Marquart-Pyatt 2016), the gap between the "values" held by people and the "actions" they take to change their behavior lead to a persistent "value-action gap" (Howell 2013; Brown and Sovacool 2018; Gifford 2011).

When applied to EVs, this collective literature underscores the importance of beliefs, attitudes, and values, but also recognizes that actions are facilitated or inhibited by internal and external conditions that include technology prices, availability, changing patterns of behavior and performance of the technology. In fact, in the case of EVs, the present level of technology requires users to make changes in driving behaviors and plan ahead proactively. This requirement might further increase the gap between users' values and actions. Also, the systemic path dependence on traditional modes of transit adds to the value-action gap in this sector.

In the following section, we qualitatively summarize the literature that explores the public perception of electric vehicles. A brief description of our survey instrument and dataset follows. Section 4.3 then describes the variables and the empirical strategy used for the analysis followed by results in Section 0. The final sections summarize the findings and provide directions for future work.

4.2 Literature Review

The literature on acceptance of EVs, growing every day, is situated in the broader context of human interaction with technology and technology acceptance. The technology acceptance model has been widely deployed in the analysis of workplace adoption of technology, such as the introduction of computers and the internet or even smart meters (Chen, Xu, and Arpan 2017). However, the model is not used to analyze individual behaviors and purchase decisions for durable products such as cars. The following paragraphs qualitatively summarize the literature on public opinion and adoption of EVs by examining the factors that influence the beliefs, values, and attitudes of respondents towards EVs, the methodology adopted in prior studies, and the regions covered.

For our study, we defined EVs as any passenger vehicle that uses energy drawn from the electric grid and stores it on board for propulsion (She et al. 2017). Our definition for electric vehicles in the literature review thus includes battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), fuel-cell electric vehicles (FCEVs) and range-extended electric vehicles (REEVs) (J. Du, Ouyang, and Chen 2017; H. Du et al. 2018; Schneidereit et al. 2015), but not other forms of electric mobility such as HEVs, e-bikes, vehicles relying on biofuel or hydrogen exclusively, or rail. Although motivations and barriers for BEVs, PHEVs, FCEVs, and REEVs may differ, we have treated them as a single class of "EVs" because that is often how they are discussed in the popular press and marketing materials. It is important to note here that PHEVs and PEVs/BEVs are combined in most studies, an exception being Vergis and Chen (2015), which distinguishes between the two types of vehicles and examines the comparative adoption rates in a retrospective analysis of the two markets.

Numerous factors affect attitudes towards EVs. These include social and demographic characteristics of respondents (and more broadly potential adopters), economic factors such as vehicle price or fuel economy, technical issues related to EVs such as range or charging time, and general preferences, attitudes, and values. We identify two overarching categories that drive perceptions of EVs – the beliefs, attitudes, and values of consumers; and the internal and external factors that might enable or constrain their ability to purchase these vehicles. The findings from the literature for each of these categories are discussed next.

4.2.1 Beliefs, Attitudes, and Values as Determinants of Opinion on EVs

Attitudes are often shaped and mediated by demographic characteristics, pro-environment behavior, and a users' perception of new technology. Among demographic characteristics, age, gender (Krause et al. 2013), and education (Carley et al. 2013; Sovacool, Kester, et al. 2018) are found to be related to the adoption of EVs. Older respondents are less likely to prefer EVs, whereas education is positively related to a preference for EVs. Contrary to the findings by Krause et al. (2013) and Carley et al. (2013), Sierzchula et al. (2014) do not find education to be a significant driver of EV sales. This lack of significance might reflect the small sample size (30) of mostly homogeneous countries in the dataset.

Environmental attitudes and the role of EVs as a means of achieving oil independence are both related to respondents' perception of EVs (Carley et al. 2013; Long et al. 2019). Egbue and Long (2012) find that the most significant barrier affecting the adoption of EVs is the perception of the underlying technology being new and unproven. Respondents who consider themselves early adopters of innovative products hold a favorable opinion for EVs (Egbue and Long 2012; Rezvani, Jansson, and Bodin 2015; White and Sintov 2017) reflecting the relationship between self-image and perception of new products.

Availability of information and the way consumers process it can also play a role in determining public opinion. Krause et al. (2013) conclude that respondents routinely underestimate the benefits of plug-in EVs, thus reflecting incomplete information. However, Flamm and Agrawal (2012) find that even though perception matters, economic factors take precedence when respondents make decisions about the vehicles they purchase. Further, in the case of products like vehicles, brand recognition can also play a role in determining consumer preferences (Long et al.

2019). This limitation brings to bear the role of constraints that affect the actual decision to adopt new, sustainable technology. Even as the respondents might have a positive attitude and an underlying interest in buying EVs, they may be constrained by their economic and social reality. We discuss this in the next section.

4.2.2 External and Internal Factors as Determinants of Opinion on EVs

Other constraining factors beyond mere demographics, attitudes, and values are the income of the household, the daily distance they drive and the number of members in the household.

Hardman, Shiu, and Steinberger-Wilckens (2016) conclude that BEV adopters can be classified into two groups, high-end and low-end, depending on the types of BEVs they purchase. These groups represent distinct socio-economic characteristics, including age, education, and income. Other studies also provide similar conclusions. For example, studies have found that respondent households with high income and wealth do seem predisposed towards greater EV adoption. In particular, studies in the Nordic countries have shown that more than half of the early adopters usually have medium to high incomes (Vassileva and Campillo 2017), in North America as well, early EV adopters showed earning incomes much higher than the median (Hardman et al. 2017). The relation with income is perhaps unsurprising given that EVs have a higher upfront cost compared to similar conventional vehicles and the market for pre-owned vehicles in the US.

In addition to income, economic factors that affect perceptions and adoption of EVs include prior ownership of vehicles, and fuel prices– both electricity and gasoline (Vergis and Chen 2015). In addition, technical factors affecting perceptions of EVs include characteristics of vehicles such as range (Carley et al. 2013; Egbue and Long 2012), availability of chargers at respondents' home and vicinity (Bailey, Miele, and Axsen 2015; Mersky et al. 2016; Vergis and Chen 2015), size and type of vehicles (Higgins, Mohamed, and Ferguson 2017; Hardman, Shiu, and Steinberger-Wilckens 2016) and charging time and infrastructure (Carley et al. 2013; Santos and Davies 2019). Vergis and Chen (2015) find that individuals are willing to pay higher amounts for better range, and reduction of charging time. The authors also find that respondents with the highest valuation for electric vehicles are willing to pay a premium of $6,000 to $16,000 for electric vehicles with the desired characteristics more than the price of comparable gasoline-based vehicles.

An important finding in this analysis that links the paper to government policy adoption is the role of financial incentives and government policies. Financial incentives or policies to support the adoption of EVs are found to be positively related to support for EVs (Mersky et al. 2016; Sierzchula et al. 2014; Santos and Davies 2019).

4.2.3 Methodology, and Geographic Coverage

Most studies of adoption of EVs analyze factors that determine EV adoption in one of two ways. The first group includes the analysis of public opinion using surveys, and the second is an assessment of existing data on EV sales and factors that lead to their adoption. That is, studies are generally either "forward-looking " or "retrospective” (Vergis and Chen 2015).

Most survey-based studies examine respondents’ attitudes towards EVs. Attitude is operationalized by looking at intent to purchase, willingness to pay, and impressions of EVs (Axsen, Bailey, and Castro 2015; Hidrue et al. 2011; White and Sintov 2017). In the case of retrospective analyses, the dependent variable is the adoption or sales of EVs or market share of EVs in the overall automobile market in the geographic region being examined (Mersky et al. 2016; Sierzchula et al. 2014).

In addition, literature reviews (Rezvani, Jansson, and Bodin 2015; Li et al. 2017), expert and stakeholder surveys (Santos and Davies 2019; Brown and Soni 2019), and focus group discussions (Flamm and Agrawal 2012) have been implemented to assess different factors that contribute to the adoption of EVs. Finally, Clark-Sutton et al. (2016) have developed indices to measure and compare the PEV readiness of 36 municipalities across the US.

Surveys include small sample analyses of respondents in limited geographic areas (Egbue and Long 2012; Flamm and Agrawal 2012; White and Sintov 2017) or more expansive projects including multi-state or country-wide studies (Axsen, Bailey, and Castro 2015; Bailey, Miele, and Axsen 2015; Clark-Sutton et al. 2016; Dumortier et al. 2015; Krause et al. 2013; Mersky et al. 2016; Higgins, Mohamed, and Ferguson 2017). Further, the analytical approaches include both quantitative and qualitative methods (Santos and Davies 2019). The use of online survey tools has expanded the coverage of survey design to multi-state and multi-city studies, which are increasingly common in the US. Finally, the multi-country "retrospective study" by Sierzchula et al. (2014) expands the geographic coverage of broader EV adoption analyses, but these studies have so far been limited to examining the success of national policies and not the public perception around it. Lastly, literature reviews (Rezvani, Jansson, and Bodin 2015; Li et al. 2017) and focus group discussions (Flamm and Agrawal 2012) have been implemented to assess different factors that contribute to the adoption of EVs. Finally, Clark-Sutton et al. (2016) have developed indices to measure and compare the PEV readiness of 36 municipalities across the US.

4.2.4 Gaps in Literature and Motivation for the Present Study

Despite the extensive (and expanding) coverage and the types of approaches taken in the literature on EVs, some limitations in the literature can be noted. First, the literature on EV adoption, especially when focused on Vehicle to Grid V2G[8], primarily emphasizes technical and economic factors but excludes or ignores "social" factors such as user patterns, behavioral routines, implicit values and other ways that users behave in non-rational or unpredictable ways (Sovacool, Noel, et al. 2018). Second, overall, studies primarily looked at stated preferences and intent to purchase. Further, for stated preference type studies of public opinion, the geographic coverage is usually limited to one country. It would be useful to see a comparison of respondents across countries to assess the relevance of specific national policies at their aggregate level, building the sets of comparative cases, especially for V2G (Sovacool, Axsen, and Kempton 2017). Further, most studies only focus on the intent to purchase EVs and do not seek to cover the role of different methods of increasing EV penetration. For example, vehicle grid integration is rapidly being proposed as a useful mechanism for promoting EVs (EAC 2018), but less is known about user preferences, values, and intentions.

Finally, there is room to expand the literature by exploring the role of environmental efforts and preference of specific vehicle characteristics, especially in the context of new technology adoption. Research in this area has focused on new technologies in computing, improving worked productivity and increase in mobile telecommunication, the application to the adoption of technology in sustainability and environment is, thus far, limited.

[8] Alternative business models such as Vehicle to Grid (V2G) leverage using the mobile storage of EVs can be leveraged for providing services to the electric grid. Some of these services include backup power, grid balancing, valley filling and demand charge reduction.

4.3 Research Methods and Data

To address these gaps, this section of the study summarizes our research design, consisting of a survey as well as an analytical framework of data analysis.

4.3.1 A Nordic Vehicle-to-Grid and EV Survey

We used an online survey instrument to collect information from respondents across the five countries in the Nordic region. The survey was distributed to over 5,000 respondents in the target region across Northern Europe (Denmark, Norway, Finland, Iceland, and Sweden). It was completed by over 5,000 random respondents (facilitated through a survey hosting firm) and 745 non-random respondents comprising of respondents that were invited to participate. In our main model, after removing redundant, incomplete, or potentially false responses such as those entered too quickly from the sample, we have a total of 4,660 respondents.

The survey elicited information on the socio-economic background of the respondents, including age, gender, number of children in the household, political affiliation, type of occupation, and income. In addition, survey also gathers information on the vehicle preferences of the respondent – their preferred mode of transit, most important factors when considering purchasing a vehicle, whether they would consider buying an EV, common perceptions regarding an EV, the daily distance driven, and the longest distance driven. Finally, as vehicle preferences are also related to the overall environmental attitudes of respondents, we also asked them about their environmental behavior in the recent past – whether they have recycled, installed energy efficient appliances or adopted renewable energy technology, reduced water usage mechanisms, or changed their diet.

4.3.2 Data Analysis

Since the dependent variable in our model is ordinal, we use logistic regression. We first run an ordered logistic regression model with a preference for EV as the dependent variable. However, the parallel odds assumption gets violated in the model. To address this, we run a Generalized Ordered Logistic regression model with the same dependent and independent variables. We cluster the standard errors at the country level. The following sections present the dependent and independent variables in the analysis.

4.3.2.1 Dependent variable

Our dependent variable is an ordinal variable that measures the respondents' "interest in purchasing an electric vehicle". The sample is limited to those respondents who have never owned an EV in the past. The response is measured on a 5-point Likert scale. The question asked is:

"In the previous question, you said you have never owned an electric vehicle. The next time you purchase a vehicle, how interested or uninterested would you be in purchasing an electric vehicle?" The options offered for the response are: "Very interested", "Somewhat interested", "Neither interested or uninterested", "Somewhat uninterested", "Very uninterested".

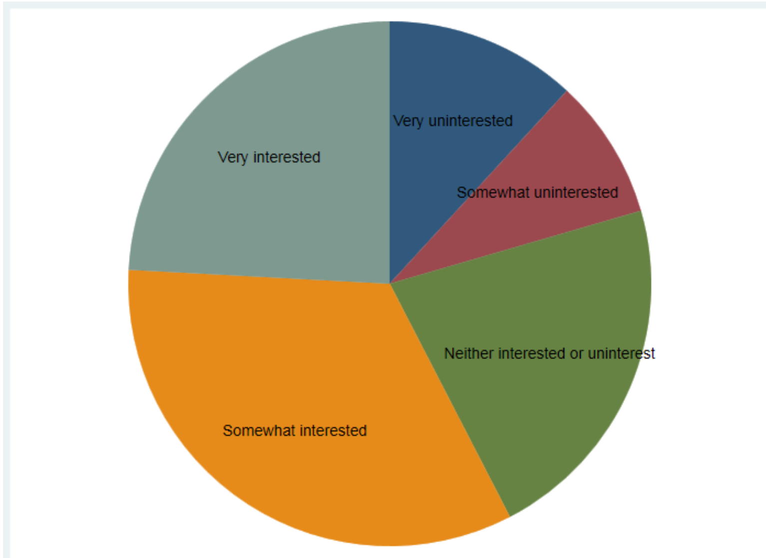


Figure 4-1: Distribution of the dependent variable

We code these options on a scale of 1-5 with "very interested" represented by 5 and "very uninterested" represented by 1. The distribution of responses across the five categories is presented in Figure 4-1. We treat the level of interest as a reflection of the respondents' attitude towards EVs as a transportation mode. A higher level of interest (Very interested and somewhat interested) reflects that respondents view EVs positively whereas those who mention being very uninterested do not have a positive attitude towards EVs.

4.3.2.2 Independent variables

The independent variables in this analysis can also be organized in the two categories as in the literature. We look at variables that represent respondents' beliefs, values and attitudes; and we also consider the internal or external factors that might present constraints towards EVs. In the former category, we look at environmental efforts and the political affiliation of the respondents. In the latter group, we include the household income, occupation, number of children, and number of adults in the household, gender of the respondent, and their daily driving distance. We discuss each of these in the following paragraphs.

4.3.2.3 Beliefs, values, and attitudes

Beliefs, values, and attitudes are represented through two variables – the respondents' environmental efforts and their political affiliation. We discuss each of these in the following paragraphs.

Environmental efforts – As mentioned earlier, the survey asks respondents about their recent efforts towards sustainable living through the adoption of energy efficiency, investment in solar panels, reduced water usage, and change in diet. We aggregate these to prepare a composite measure of environmental efforts. The variable takes discrete integer values from 0 to 5, with 0 representing no recent efforts towards sustainability. We expect the respondents' performance to be positively related to their preference for EVs.

Political affiliation – Political affiliation is related to respondents' acceptance of new technology, especially when related to energy and the environment. We expect more politically

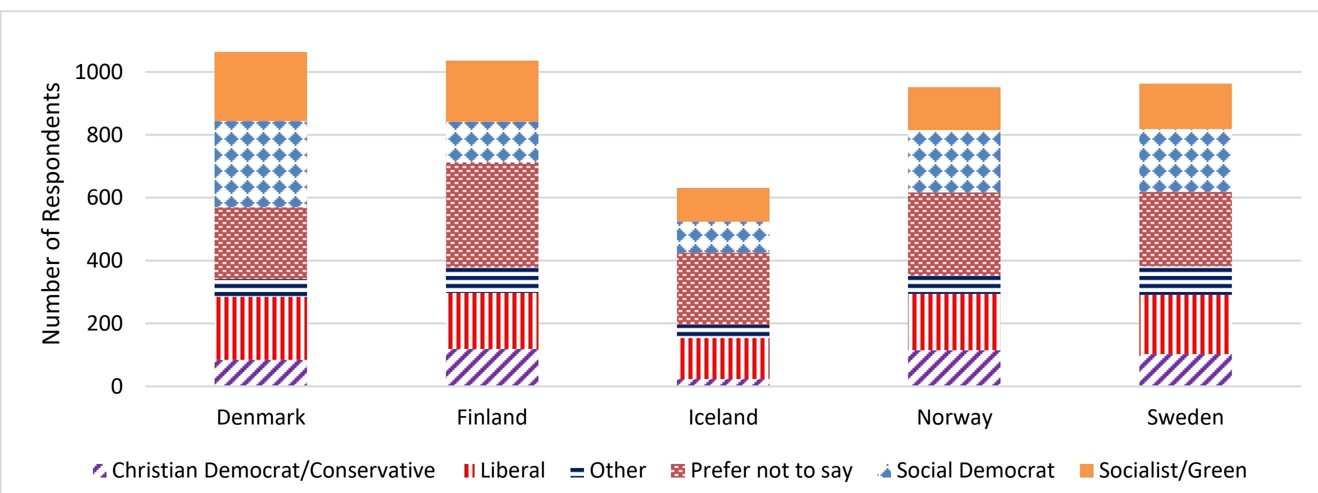


Figure 4-2: Political Leaning of the Respondents

conservative respondents to be less interested in EVs. We code political affiliation as a set of dummy variables. The group of variables includes Socialist Green, Social Democrat, Christian Democrat/Conservative, Liberal, Prefer Not to Say, and Other. Socialist Greens are the base group, and we compare the relative probabilities of other groups with them (Figure 4-2). It is interesting to note that a significant proportion (>20%) of respondents did not prefer to disclose their political affiliation. Besides, there are some variations across the countries. Denmark has a larger share of Social Democrats (26%) and Socialist/Greens (21%). Iceland has the fewest share of Christian Democrat/Socialists.

4.3.2.4 External and internal constraints

Internal and external factors include enablers and constraints such as income, family structure, occupation types, and driving behavior.

Household income – the respondents were asked to report their after-tax yearly total household income. They were provided seven categorical response options to choose from: ≤ €10,000; €10,001 to €30,000; €30,001 to €50.000; €50,001 to €70,000; €70,000 to €90,000; > €90,000; and Prefer not to answer (Figure 4-3). We code the responses into six incremental categories; the response "Prefer not to answer" is coded as missing. We expect that households with higher incomes are more likely to show interest in buying an EV.

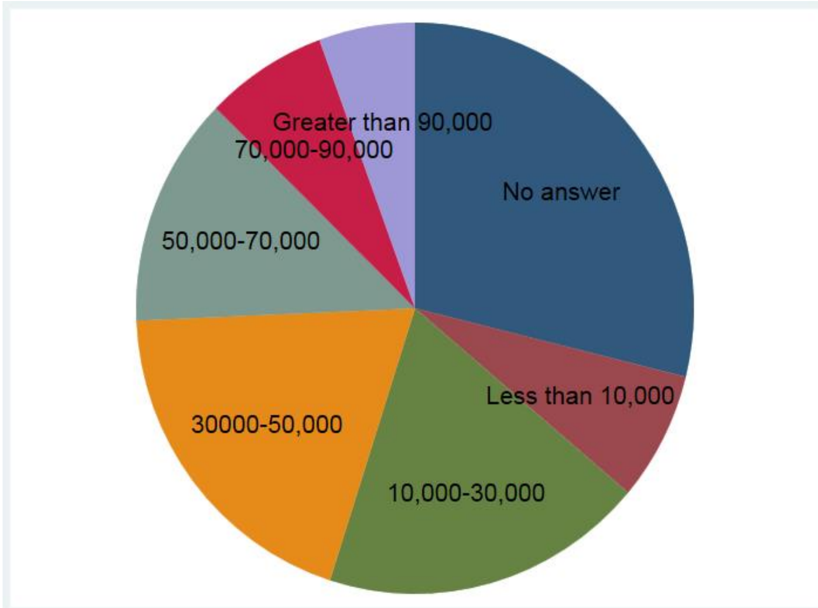


Figure 4-3: Distribution of income across the dataset (in euros)

Examining the country-wise distribution of the income (Figure 4-4), from those who responded to the question, a large proportion of the respondents are in the middle two categories, €10,000-30,000 and €30,000-50,000.

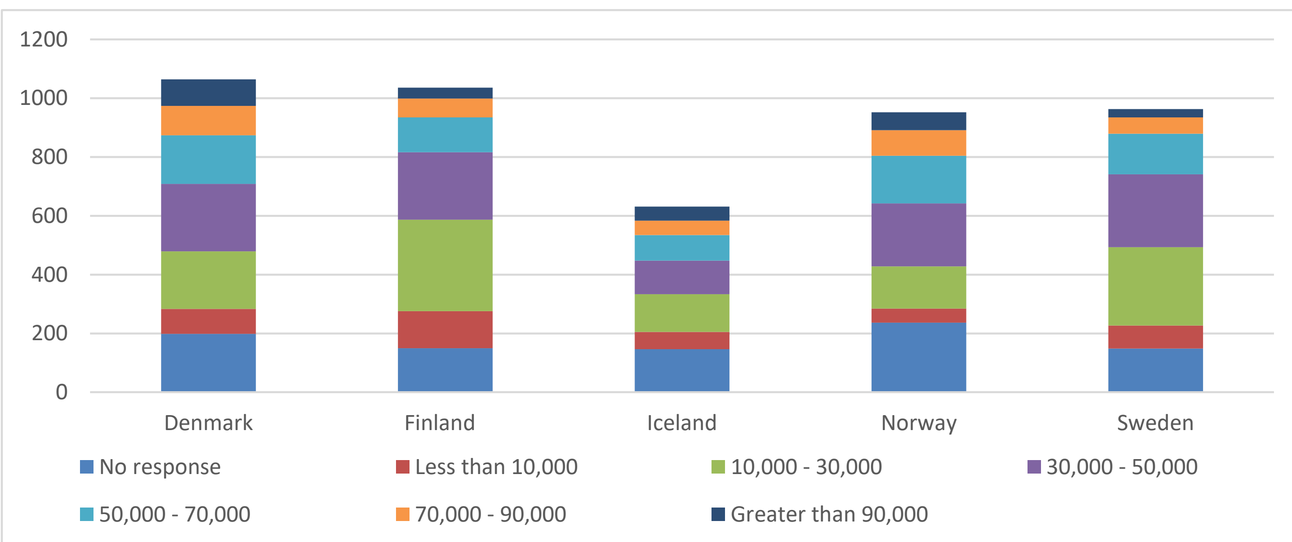


Figure 4-4: Income distribution across countries

Occupation – The respondents were given nine options to choose their occupation. These include the private sector, non-profit, or nor governmental organization, government, academic institutions, retired, unemployed, student, prefer not to answer, and others. Those responding other were then asked to provide their occupation type manually. We code occupation types as a set of dummy variables with those working for academia as the reference group.

Number of children in the household – Having children can have two different, contradictory effects. First, respondents with children would be more concerned about the environment and therefore show interest in EVs. However, current models of EVs are compact cars or sedans, which may be unsuitable for families with several members. Most of the respondents (3,900) reported one child in the household. For those who reported more than four children, we combined to form one category of four or more children.

Gender – Males and females respond differently to new technology. Males might be more likely to adopt new technology based on the perceived usefulness, whereas females are more likely to adopt new technology based on ease of use. In previous research (IEA 2018b), males have been found to perceive EVs more positively than females. We expect this to be true in our data as well.

Daily driving distance – Finally, most EVs in the market currently have limited battery size and, consequently, range. The respondents reported their average daily driving distance by selecting one of the following categories: ≤ 20 km, 20-50 km, 50-80 km, 80-100 km, ≥ 100 km, and “I don't regularly drive a car.” We code daily driving distance as a categorical variable that takes values 0 through 5. Table 4-1: Summary Statistics – Dependent and Independent Variables presents the descriptive statistics of the dependent and independent variables.

Table 4-1: Summary Statistics – Dependent and Independent Variables

VARIABLES	Mean	Std. Dev	Min	Max
Level of interest in EV	3.49	1.27	1	5
Beliefs, Values and Attitudes				
Political Leaning=Socialist/Green	0.17	0.38	0	1
Political Leaning=Christian Democrat/Conservative	0.10	0.29	0	1
Political Leaning=Liberal	0.19	0.39	0	1
Political Leaning=Other	0.07	0.26	0	1
Political Leaning=Prefer not to say	0.28	0.45	0	1
Political Leaning=Social Democrat	0.19	0.40	0	1
Composite score of all environmental efforts (#)	2.04	1.35	0	5
Internal and External Constraints				
Household Income	2.50	1.73	0	6
Occupation=Academic institution	0.11	0.31	0	1
Occupation=Non-profit/non-governmental organization	0.10	0.29	0	1
Occupation=Other	0.04	0.20	0	1
Occupation=Prefer not to say	0.03	0.18	0	1
Occupation=Private sector	0.06	0.23	0	1
Occupation=Retired	0.29	0.46	0	1
Occupation=Student	0.14	0.34	0	1
Occupation=Unemployed	0.16	0.36	0	1
Female (Male = 0)	0.49	0.50	0	1
Adults (#)	1.79	0.69	1	4
Children (#)	1.39	0.84	1	4
Daily Distance Driven	1.29	1.24	0	5

The survey also elicited responses on vehicle preferences (Figure 4-5). Safety is reported to be very important for the majority of respondents, followed by the fuel economy and price, which indicate the economic viability of operating and owning an EV, respectively.

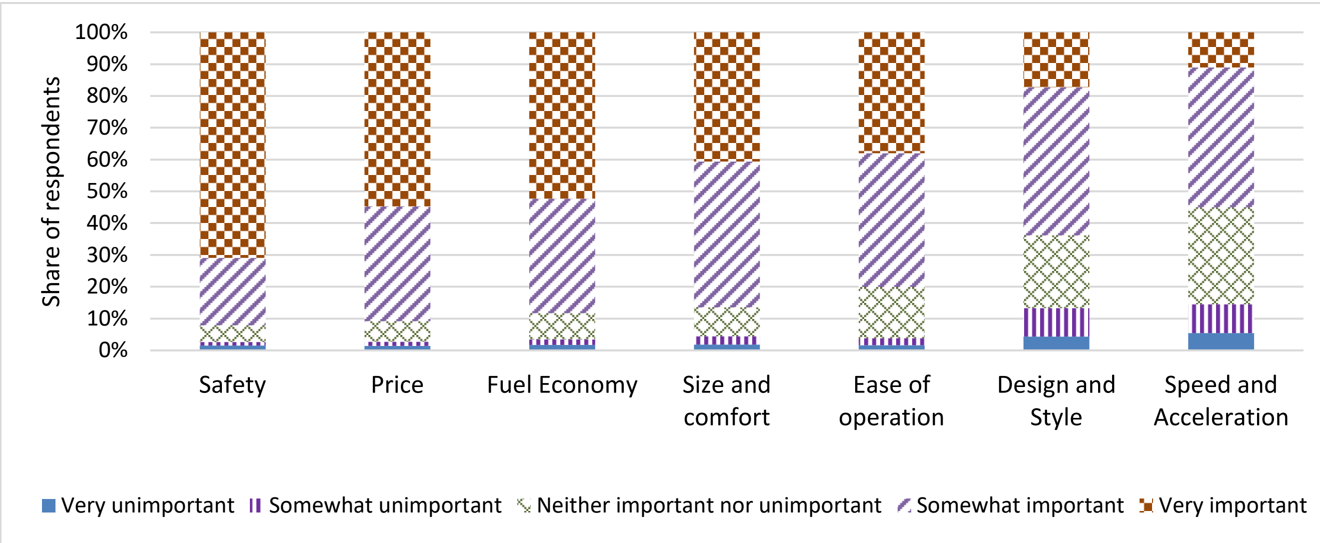


Figure 4-5: Relative importance of vehicle characteristics

4.4 Results

Table 4-2 presents the results of the Generalized Ordered Logit Model. We run the model in Stata using the gologit2 command with the "autofit" option to allow for a more restrictive model to be applied for variables that violate the proportional odds/parallel-lines odds assumption (Williams 2006). We report the probability changes for the different response categories and discuss them briefly in the following paragraphs. In this section, we present general results according to vehicle ownership and performance; beliefs, values, and attitudes; and internal and external constraints.

Table 4-2: Model Results for demographics and political affiliation and EV and V2G preferences

VARIABLES	(1) Income	(3) Occupation - Government	(4) Occupation – NGO/NPO	(5) Occupation – Other	(6) Occupation – Prefer not to say	(7) Occupation – Private	(8) Occupation – Retired	(9) Occupation – Student	(10) Occupation – Unemployed
1. Very uninterested	-0.00843***	0.0234*	0.0694***	0.0534	0.0960***	0.0353***	0.106***	0.00162	0.0459***
	(0.00144)	(0.0126)	(0.0235)	(0.0357)	(0.0267)	(0.0110)	(0.0364)	(0.0150)	(0.00854)
2. Somewhat uninterested	-0.00477***	0.0167*	0.0439*	0.0356	0.00995	0.0246***	0.0173	0.0204*	0.00605
	(0.000627)	(0.00904)	(0.0254)	(0.0226)	(0.00761)	(0.00952)	(0.0161)	(0.0116)	(0.00961)
3. Neither interested nor uninterested	-0.00540***	0.0238**	0.0881***	0.0439**	0.0974***	0.0330***	0.0696***	0.00987	0.0637***
	(0.00112)	(0.0112)	(0.0232)	(0.0186)	(0.0339)	(0.00947)	(0.0203)	(0.0219)	(0.0119)
4. Somewhat interested	0.00457***	-0.00949	-0.119***	-0.0301	-0.142***	-0.0170*	-0.0717***	-0.0541***	-0.0303**
	(0.00128)	(0.00880)	(0.0396)	(0.0241)	(0.0336)	(0.0102)	(0.0224)	(0.0173)	(0.0138)
5. Very interested	0.0140***	-0.0544**	-0.0828***	-0.103*	-0.0613	-0.0759***	-0.122***	0.0223	-0.0854***
	(0.00301)	(0.0245)	(0.0246)	(0.0529)	(0.0606)	(0.0208)	(0.0266)	(0.0483)	(0.0263)

	(11) Christian Democrat Conservative	(12) Liberal	(13) Other	(14) Prefer not to say	(15) Social Democrat	(16) # Children	(17) # Adults	(18) Female	(19) Environmental efforts	(20) Daily driving distance
1. Very uninterested	0.0591***	0.0156***	0.0748***	0.0459***	0.0141	-0.0203***	-0.0117**	0.0148	-0.0346***	0.00375
	(0.0176)	(0.00430)	(0.0221)	(0.0151)	(0.0105)	(0.00413)	(0.00498)	(0.0108)	(0.00791)	(0.00564)
2. Somewhat uninterested	0.0214	0.0157*	-0.00366	0.00288	0.00693	-0.0115***	-0.00663*	-0.00782	-0.0110***	0.00212
	(0.0193)	(0.00806)	(0.0151)	(0.00966)	(0.0141)	(0.00316)	(0.00345)	(0.00836)	(0.00278)	(0.00299)
3. Neither interested nor uninterested	0.0927***	0.0743***	0.0718***	0.121***	0.0893***	-0.0130***	-0.00750*	0.0463***	-0.0238***	0.00240
	(0.0286)	(0.0180)	(0.0180)	(0.0104)	(0.00405)	(0.00437)	(0.00418)	(0.00729)	(0.00411)	(0.00328)
4. Somewhat interested	0.00212	-0.0213	-0.0594**	-0.0252	-0.00182	0.0110***	0.00636**	-0.00197	0.0166**	-0.00203
	(0.0339)	(0.0163)	(0.0240)	(0.0200)	(0.0259)	(0.00295)	(0.00257)	(0.0159)	(0.00729)	(0.00309)
5. Very interested	-0.175***	-0.0843***	-0.0835***	-0.145***	-0.108***	0.0338***	0.0195*	-0.0512**	0.0528***	-0.00623
	(0.0529)	(0.0208)	(0.0189)	(0.0230)	(0.0143)	(0.0108)	(0.0106)	(0.0206)	(0.00434)	(0.00888)

# of observations: 4,658; *, **, and *** indicate significance at the 0.05, 0.01, and 0.001 levels, respectively.

4.4.1 Vehicle Ownership

A large majority of the respondents owned a vehicle – 3,994 owned at least one vehicle, 1,205 owned two cars, and 1,149 reported ownership of three or more cars in the household.

4.4.2 Beliefs, Values, and Attitudes

We find that political affiliation and attitude towards EVs are related. Using classifications for Europe, those who identify as Christian Democrats or Conservatives, are on average, 18% less likely to be very interested in EVs when compared with Socialist Greens. In fact, for the group of respondents who reported being "very interested," all political affiliations are less likely to be "very interested" in EVs than Socialist Greens. Social democrats and those who did not reveal their political affiliation are also less likely than comparable Socialist Greens to be very interested in EVs.

As hypothesized, the relationship between respondents' environmental efforts and preference for EVs remains consistent and significant across all categories. With every level increase in the number of environmental initiatives taken by the household, the probability of being very uninterested, somewhat uninterested, and neither interested nor uninterested in EVs decreases. On the other hand, the probability of being somewhat and very interested in EVs increases with an increase in the number of environmental initiatives taken by the respondent.

4.4.3 Internal and External Constraints

As noted earlier, respondents' interest in EVs can be moderated significantly by certain internal and external factors. These factors can further be classified into economic and social constraints. For example, income and interest in EVs are strongly related; occupation is also a determinant of attitude towards EVs. Respondents working for the government, for non-profits, private sector, retirees, and unemployed people, are all less likely than those working in academia to be interested in EVs. The results seem to be more significant at the two extremes – for those who are either very uninterested or very interested. Those working for non-profit organizations are less likely than academics to be interested in EVs. While we don't know the reason for this difference, we can speculate that the academics might be more aware of new technology and the environmental implications of EVs; their ability to adapt and accept such changes might be higher.

We also note a positive relation between interest in EVs and the number of children in a household – as the number of children increases by one, the probability of a respondent being very interested in an EV increases by more than 4% points. Perhaps this reflects shorter trips of families with young children.

We run two additional alternative specifications. The first examines specific environmental efforts in more detail, and the second explores the effect of different vehicle preferences on interest in EVs. In both cases, to account for a large number of independent variables in the model and the potential absence of variation in the five level-dependent variables, we reconfigured the dependent variable into binary – 0 represents lack of interest/ambivalence towards EVs and the 1 is interest (somewhat and very interested).

For the first analysis, we look at the five different environmental efforts variables included in the survey – spending on energy efficiency, solar, change in diet, recycling, and reduced water usage (Figure 4-6). We find that efforts to recycle have the largest average marginal probability changes on interest in EVs. Respondents who recycle are, on average 17% more likely to be interested in EVs than comparable respondents who do not recycle. This is followed by dietary changes (8%) and installing energy-efficient appliances (6%). On the other hand, reducing water usage and installing solar panels are not significantly related to the level of interest in EVs. The full results are presented in Appendix A (Table A2).

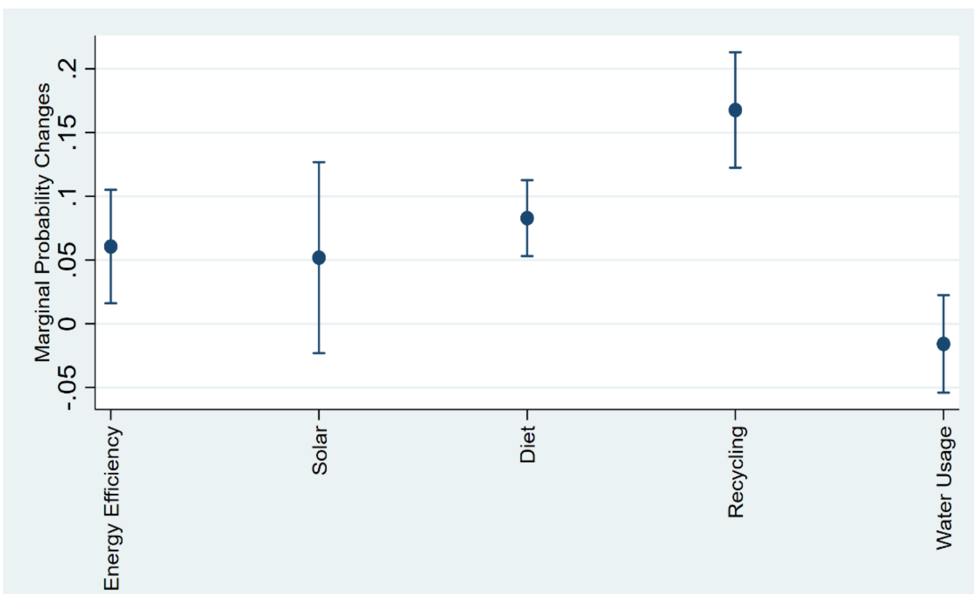


Figure 4-6: Average marginal probability changes for environmental efforts

In the second alternative specification, we include all the variables that reflect the respondents' vehicle preferences. We include six additional independent variables - speed and acceleration, size and comfort, design and style, ease of operation, safety, fuel economy, and price. Each variable is ordinal, with values from 1 to 5 where 1 represents that the factor is "very unimportant" and 5 – "very important." The full results are included in Appendix A (Table A3). All factors that determine preferences for cars (except price) are positively related to the respondents' interest in EVs (Figure 4-7).

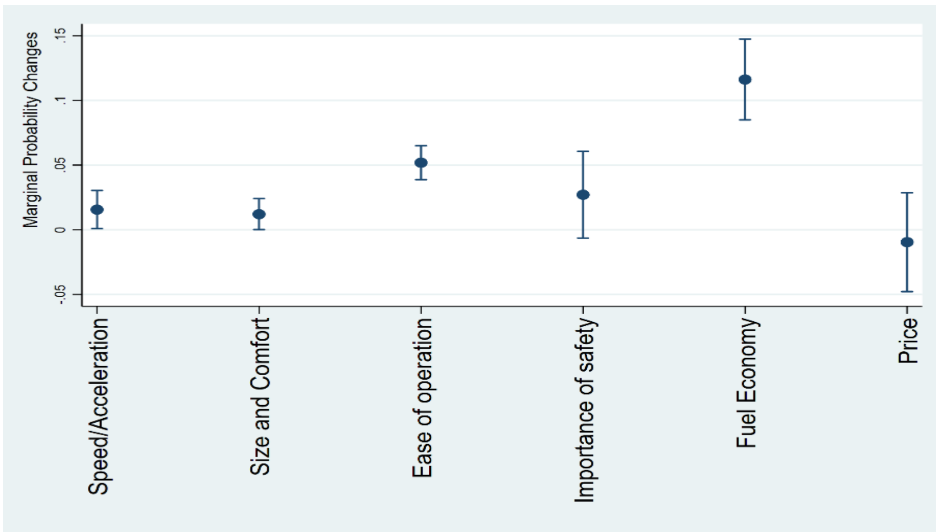


Figure 4-7: Average marginal probability differences for vehicles characteristics

Among the vehicle characteristics, fuel economy has the largest coefficient. For every one-level increase in fuel economy as a vehicle characteristic, respondents are, on average, nearly 12 % points more likely to be interested in an EV. Ease of operation is the next most important vehicle characteristic – with each level increase in its importance, respondents were 5% points more likely to be interested in EVs. While the coefficient of price is negative, it is not significant, so we do not discuss its implications here.

4.4.4 Country-Wise Analysis

To examine variations across the five countries in the survey, we also run the analysis for each country. Since doing this reduces the number of observations and makes it difficult to impose the five categories of the dependent variable, we transform the dependent variable into a dichotomous variable.

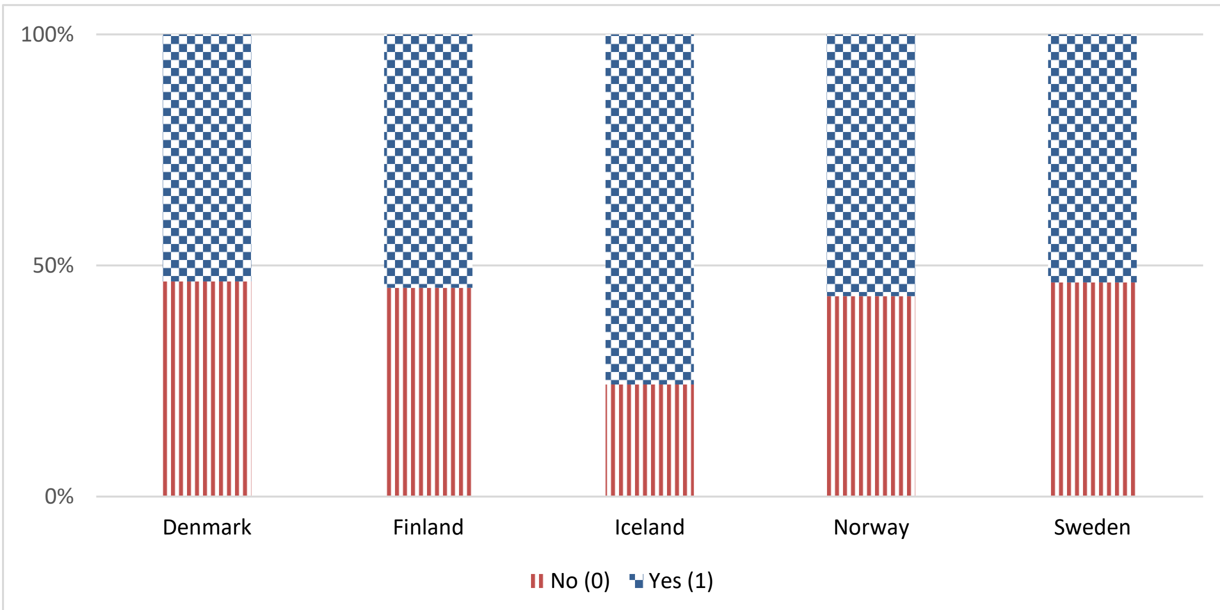


Figure 4-8: Interest in EVs across countries

Those who responded that they were “Very uninterested”, “Somewhat uninterested”, and “Neither interested nor uninterested” were all coded as 0 and those who responded that they were, “Somewhat interested” and “Very interested” are coded as 1 (Figure 4-8). This changes the distribution of the dependent variable and allows us to run a logistical regression model with a binary dependent variable. A majority of the respondents in each country are (somewhat or very) interested in EVs. With 478 out of 631 respondents interested in EVs, Iceland has a disproportionate representation of those interested in EVs.

The average marginal probability differences (Table 4-3) indicate some interesting variation across the countries.

Table 4-3: Country-wise analysis: Drivers of interest in EVs

(Marginal probability changes reported here)

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Denmark	Finland	Iceland	Norway	Sweden
Household Income	0.00830	0.0185*	0.0225**	0.0182**	0.0261**
	(0.00899)	(0.0111)	(0.00904)	(0.00864)	(0.0113)
Occupation = 2, Government	-0.131**	-0.0914	-0.0378	-0.0801	-0.0925
	(0.0609)	(0.0739)	(0.0771)	(0.0682)	(0.0793)
Occupation = 3, Non-profit/NGO	-0.420***	-0.0962	-0.151	-0.116	-0.205**
	(0.0854)	(0.0768)	(0.117)	(0.0914)	(0.0963)
Occupation = 4, Other	-0.255***	-0.0461	-0.115	-0.339***	0.0711
	(0.0932)	(0.0974)	(0.116)	(0.101)	(0.0892)
Occupation = 5, Prefer not to say	-0.388***	-0.104	-0.105	-0.228***	-0.281***
	(0.0797)	(0.0798)	(0.0908)	(0.0881)	(0.0924)
Occupation = 6, Private sector	-0.181***	-0.0609	-0.0260	-0.0818	-0.0980
	(0.0466)	(0.0567)	(0.0712)	(0.0568)	(0.0652)
Occupation = 7, Retired	-0.283***	-0.0615	0.0482	-0.260***	-0.216***
	(0.0514)	(0.0628)	(0.123)	(0.0650)	(0.0731)
Occupation = 8, Student	-0.153***	-0.0110	-0.0135	-0.0864	-0.0132
	(0.0574)	(0.0643)	(0.0720)	(0.0624)	(0.0745)

Occupation = 9, Unemployed	-0.204***	-0.0352	0.0631	-0.106	-0.134*
	(0.0623)	(0.0667)	(0.0982)	(0.0754)	(0.0809)
Political Leaning = Christian Democrat/Conservative	-0.236***	-0.163***	-0.362***	-0.0863	-0.0935
	(0.0588)	(0.0563)	(0.0879)	(0.0609)	(0.0611)
Political Leaning= Liberal	-0.141***	-0.0884*	-0.152**	-0.0745	-0.0665
	(0.0483)	(0.0508)	(0.0681)	(0.0551)	(0.0545)
Political Leaning= Other	-0.139**	-0.141**	-0.128	-0.105	-0.157**
	(0.0702)	(0.0620)	(0.0913)	(0.0712)	(0.0647)
Political Leaning= Prefer not to say	-0.142***	-0.230***	-0.211***	-0.163***	-0.131**
	(0.0456)	(0.0415)	(0.0605)	(0.0513)	(0.0514)
Political Leaning= Social Democrat	-0.139***	-0.167***	-0.145**	-0.0498	-0.0477
	(0.0435)	(0.0532)	(0.0697)	(0.0536)	(0.0550)
Children	-0.0287	0.0449**	0.0339**	0.0164	0.0363
	(0.0191)	(0.0209)	(0.0161)	(0.0218)	(0.0236)
Adults	-0.0309	0.0253	0.0171	0.0352	0.0411*
	(0.0233)	(0.0242)	(0.0218)	(0.0220)	(0.0232)
Female	-0.0510*	-0.131***	-0.0207	-0.0234	-0.0766**
	(0.0309)	(0.0298)	(0.0345)	(0.0332)	(0.0316)
Composite score of all environmental efforts	0.0756***	0.0831***	0.0436***	0.0744***	0.0732***
	(0.0103)	(0.0102)	(0.0149)	(0.0108)	(0.0109)
Daily Distance Driven	-0.0143	0.00786	-0.0171	-0.0534***	-0.00396
	(0.0117)	(0.0134)	(0.0156)	(0.0148)	(0.0135)
Observations	1,064	1,036	631	952	963

Income is a significant determinant of interest in EVs for Finland, Iceland, Norway, and Sweden, but not in the case of Denmark, whereas the type of occupation is significantly related to the probability of being interested in EVs. As in the all-country model, the base category of employment is Academia. We find that in Denmark, all other occupation types are less likely to be interested in EVs than academics.

Political affiliation plays a role in driving EV interest in Denmark, Finland, and Iceland, where those who identify as Socialist/Greens are more likely to show interest in EVs than comparable respondents with other political affiliations. The most significant difference is between the Social/Greens and Christian Democrats/Conservatives in Iceland, where the latter group is 36% points less likely to be interested in EVs. Among family and social variables, the number of children is significantly and positively related to the interest in EVs in Finland and Iceland but not in the other three countries. Having one more child makes respondents 4 and 3% points more likely to be interested in EVs in Finland and Iceland, respectively.

Finally, examining the environmental efforts and driving behavior of the respondents, we find that taking steps towards sustainability is highly significant in all five countries. Each additional measure to reduce the environmental footprint increases the probability of being interested in EVs by anywhere between 4 (Iceland) and 8 (Norway) % points. Driving behavior is significantly related to interest in EVs only in Norway, where each level increase in daily driving distance decreases the probability of being interested in EVs by 5% points.

4.5 Discussion

This paper provides insights on the beliefs, values, and attitudes, and the internal and external constraints that impact preferences for EVs and V2G mobility across the five Nordic countries. We find that a variety of social, political, and economic factors affect public perceptions. Our findings largely align with prior studies. However, using the generalized ordered logit model and many explanatory variables from our survey instrument, we examine the relation between several factors that represent values and attitudes of respondents towards EVs.

Social factors such as the gender of the respondent and the number of children in the household affect the perception of EVs. Female respondents are less likely to be interested in EVs, whereas respondents with children in the household are likely to have a high average marginal probability of being interested in EVs. Income is also influential as it determines the level of affordability; it is positively related to interest in EV. Political affiliation confirms our hypothesis that those who politically identify with the Socialist Greens are most supportive of EVs. Further, the occupation of respondents is also a determinant of preferences for EVs. Academicians are more likely to be interested in EVs than those engaged in other professions. This could in part be due to their greater awareness of recent research and technology advances and the link between clean air and electric mobility. We also note that interest in EVs is related to other environmental activities of respondents. Respondents who have made efforts towards reducing water and energy consumption and changing aspects of their lifestyles to be more sustainable are more likely to be interested in EVs as another way of reducing their energy consumption and consequently, emissions (and possibly vice versa). These groups of people – academics, and others with more sustainable lifestyles can be the catalysts of phasing in the new era of electric and sustainable mobility.

Finally, in our analysis of different vehicle characteristics and their relation to the level of interest in EVs, we find that fuel economy, the price of vehicles and ease of operation are significantly related to the level of interest in EVs. Using the different levels from a hierarchy of user needs discussed in the introduction, this reflects the importance of functionality, reliability, and usability as determinants of interest in EVs. Importance of design and style, which would be an indicator of creativity, operate at the highest level in the hierarchy of needs, yet are not significantly related to interest in EVs.

We do note a few limitations of this study. First, the data for the analysis is based on an online survey of respondents. As such, we rely on the stated preferences of the respondents and do not have their behavior through observed and revealed preferences. This could further the gap between the intentions and actions that we aim to study through this paper. However, the use of Nordic region helps us address that limitation to some extent since the region has witnessed some of the highest levels of EV penetration. Further, we cannot observe the linkages between policies and EV adoption in the region since we do not seek the information on respondents' awareness of EV technology. Some of these gaps highlight a path for future research. First, comparing the responses of those with experience of using EVs with the respondents who show high levels of interest in the technology might help understand the factors that bride the gap between revealed and stated interests. Further, using the IEA databases to summarize the policies in place in the five countries and the levels of EV sales could also be a way of estimating the impact of government incentives in driving technology adoption.

CHAPTER 5. CONCLUSIONS

5.1 Summary of findings

This dissertation examines the factors driving and the potential implications of a growing EV market. Battery operated EVs that charge using electricity present a solution to mitigate the climate impacts of the transportation sector. Since the introduction of relatively affordable EV models such as the Nissan Leaf in 2011, the Tesla Model S in 2012, and the BMW i3 in 2013, the market for electric vehicles witnessed an unprecedented uptake of the new technology. There are currently over 30 models of EVs in the US markets alone, an exponential growth from just two in 2011 (AFDC 2020; EERE 2020). Global projections put the estimated sales of EVs at 55 million in 2025 and 135 million by 2030 (IEA 2019). This growing market is related to employment, policy choices and public interest. The three papers in this dissertation analyze these relations and aim to answer research questions in each area (Table 5-1).

As the global sales of EVs increase, so will the effect on employment in associated industries. Using and input-output modeling approach, the first paper compares the employment effects of investments in EVs and comparable ICEVs. The comparison relies on assumptions regarding the current cost distribution of EVs and assumes that batteries form over 40% of the total vehicle cost. The paper concludes that the total employment in EV manufacturing will not be very different from the ICEV market. However, within the total manufacturing, there will be differences in specific component industries. For example, since batteries comprise the largest share of EV costs currently, investment in EVs will also lead to jobs in batteries. These jobs will replace the current ICEVs based jobs in auto-parts manufacturing. Further, the distributional implications are even stronger when comparing the operational expenditures in the two industries. The largest difference will be in the fuel costs – with electricity replacing the traditional gasoline-based automotive fuel market in the US. The second paper examines the evolution of policy design and the effectiveness of instrument choice over time across US states. The policy landscape both determines the trajectory of the EV market and responds to rising sales. The research shows evidence of policy adoption, repurposing, and retraction over time. As the market increases in size and states realize the financial impact of providing incentives to EV owners, policies get retracted and repurposed. Another trend in the introduction of new policies is the presence of the private sector. As power companies realize the potential demand from the growing EV sector, they have put in place incentives and programs to support EV buyers, i.e., the eventual electricity consumers. Finally, examining the long-term duration of these policies, despite the perceived financial costs, government-provided incentives, on average last longer than regulations. As regards the effectiveness of policies, the paper concludes that policies do lead to an increase in sales (as measured by log sales, share of EVs in total new car sales, and per capita EV sales). Further, the marginal effects of different policy tools (government incentives, regulations, and utility incentives) differ.

Finally, the success of policies and growth of the EV sector hinges, in large part, on the level of public interest in EVs. In the survey of respondents across the Nordic countries, the third paper finds that socio-economic variables are related to interest in EVs. Second, respondents' political affiliation is related to their interest in EVs – respondents with almost all political identities are less likely than their green party counterparts to be interested in EVs. Further, analyzing the respondents' investments in other environmentally sensitive areas, the paper concludes that activities such as investing energy-efficient appliances, changing dietary behavior, and practicing recycling are all positively associated with interest in EVs.

Table 5-1: Summary of research questions and findings

Area	Research Questions	Findings
Employment effects	What is the total effect of increasing Electric Vehicle sales on employment in the US?	The total employment is not likely to change much due to the shift from EVs to ICEVs.
	How is this effect distributed across different industries/sub-sectors?	The distribution of jobs will change a lot with the jobs in petroleum being lost and substituted by technology-oriented jobs such as electronics and battery manufacturing.
Policy design and effectiveness	How has the landscape of EV policies evolved?	The policy landscape witnessed much movement in this area with the introduction, retraction, and repurposing of policies over the years.
	Does the choice of policies and instruments determine the state-level EV sales?	Policy choice is related to the different outcome measures of EV sales. Incentives and regulations are both related to higher EV sales with

Area	Research Questions	Findings
		different instruments having different effects on EV sales.
Public perception	What determines people's levels of interest in EVs? What are the external and internal factors moderating the effect of beliefs and values in determining the interest in EVs?	Interest in EVs is determined by the socio-economic factors such as income, gender of the respondent, and occupation type. Beliefs and attitudes as reflected in the political affiliation and other environmental efforts also affect the levels of interest in EVs.

5.2 Contribution to research

This dissertation expands on research in the energy and environment policy by examining the second-order effects of the changing transportation and energy markets.

The first paper takes a comprehensive view of the automotive manufacturing and operations expenses. As noted in the paper, the research builds on prior works such as those by Garrett-Peltier (2017) and Turner et al. (2018), and the findings contribute to the understanding of the potential impacts of transitions to sustainability and areas where employment and labor policy could pre-emptively address changing markets and the evolving technological needs of the sectors (Vona et al. 2018).

The second paper adds to the work on policy design choices and effectiveness. Studies in the field of energy and environmental policy have primarily been focused on looking at policy diffusion and amendment (Matisoff and Edwards 2014; Carley, Nicholson-Crotty, and Miller 2017). This paper goes beyond and tests the effects of EV support policies on sales-related outcome variables. It also looks at the choice between different types of policies and determines the marginal effects of different design choices. Further, the exploration of utility-provided incentives provides a space for linking energy and environmental policy with the idea of publicness and the private provision of public goods (Rainey 2009; Bozeman and Bretschneider 1994; Moulton 2009).

The third paper contributes to the vast literature on public interest in EVs and factors that drive it (Carley et al. 2013; Egbue and Long 2012; Sovacool 2017). The paper adds to the literature by making a distinction between beliefs and attitudes that might support interest in EVs, and the external and internal factors that might limit respondents' ability to invest in new technology. The paper also examines the beliefs and attitudes of respondents by measuring and including factors such as investments in other environmental activities and political affiliation as potential explanatory variables determining interest in EVs.

5.3 Implications of the Covid-19 Pandemic

As noted in Chapter 1, the outbreak of global pandemic has throttled the economy and energy sectors. As mobility has reduced with nationwide lockdowns across the globe, so has the demand for vehicles and petroleum. This will likely have implications on all aspects of the EV sector has well. The following paragraphs briefly discuss the implications of the pandemic for each pf the research projects in this dissertation.

Employment. In the short-term, as the economy reels from widespread shutdowns and the resulting lack of income and demand, the overall demand for automobiles, include EVs is likely to fall as has been noted by the IEA (2020). However, the response of the market will be uneven and in part, driven by the response of the governments in the types of incentives and relief packages implemented to help the economy and the different sectors. Furthermore, this is complicated by the competing effects and pressures on global supply chains. While the demand for personal mobility has declined, freight activity has continued to increase and respond to the growing pressures on global supply chains. As government reconsider reliance on international markets, the demand for petroleum might also get affected beyond the short-term fluctuations that have already been witnessed.

Policy. EV incentive policy will face two major challenges in the near to medium term. Several government incentives are nearing their pre-designated end periods. Further, the support from the federal government has also reduced as most EV manufacturers reached the sunset point of 200,000 vehicles sold. The short- to medium-term decline in transportation activity might reduce the need for states and local governments to introduce any more policies to support the EV industry. Particularly, as fiscal pressures increase, the goal of supporting economic revival might be take precedence over environment policy. However, several federal polices to support the adoption of EVs were passed as a response to the 2008 economic crisis.

Public Perceptions. Finally, examining the potential implication of the pandemic on the perceptions of EVs, the most immediate impact would be on the consumers' internal factors – i.e. their purchasing power. Since EVs are typically more expensive than the comparable ICEVs, we might witness a reduction in the level of interest in EVs. On the other hand, the need to social distance might lead potential customers into the market for automobiles. For example, consumers who depend on public transit might seek alternative modes of commuting. Additionally, single car households might look to purchase a secondary vehicle to reduce dependence on public transit and follow social distancing guidelines. However, if the low oil prices persist, the additional demand for vehicles might be met through ICEs and the demand for EVs might continue to remain low. The response of the market would potentially vary based on geography as has already been witnessed (IEA 2020).

5.4 Future Work

I plan to build on the work done in this dissertation in each of the three papers – employment in clean energy transitions, examining policy design and effectiveness, and public interest in EVs.

Continuing to examine the employment effects of the EV sector, I plan to focus specifically on the battery industry, estimating the job and skill requirements. Further, an associated change with the battery and EVs markets is likely to shift the location of jobs and industries. The geographic shift can potentially recreate similar effects as the automation of the coal sector and the emergence of the rust belt in automotive manufacturing.

Expanding on the work on policy design and effectiveness, I hope to dig deeper into the policy adoption process. First, developing additional metric to look at strength of policy and going beyond the current measure of policy count would help understand the connection between policies and EV sales. Next, as many state-level incentives reach their sunset points, testing for the potential implications of these imminent changes and the response from other entities in the space will provide a way of exploring the role of policy substitution and the completeness of such substitution. Further, EVs are also being linked to the growing interest in autonomous vehicles. As such, examining the changes in regulations would provide a way to examine the co-existence of two technologies.

Advancing on the research on interest in EVs, a potential future approach would be to test the interest in EVs among car dealers and the issues they face. This research will also potentially connect with the work on the employment effects of the EV markets. As noted in Chapter 4, further examining, ad comparing and contrasting the groups that reveal the highest levels of interest in EVs with those who report owning an EV in the past will provide useful insights into the gaps between stated and revealed preferences.

Finally, overarching the three studies in this dissertation is the linkage between environment, government policy and the citizen-customers. Going forward, I will look to explore other avenues where similar relations emerge. One obvious case the emerging set of regulations around autonomous vehicles and the role of state policies. Further, in many cases, the EV drivetrain is being used as the base technology on which the AV technology is being overlaid. Exploring this space to compare the role of different agencies in policy design and implementation along with public perception of the technology may provide interesting insights into the field. Further, the auto manufacturing industry lies at the heart of both AVs and EVs – therefore offering a common perspective on the effect of these sectors on changing nature and distribution of employment. Exploring these aspects in future studies would provide insights on the reliance of the economy on this sector and the emergence of regional growth centers in auto-manufacturing and allied industries.

APPENDIX

Table A1: Results from the ordered logistic regression

	VARIABLES	Interest in EVs (0/1)
	Household Income	-0.00699*
		(0.00390)
Occupation (Reference = Academics)	Government	0.0315**
		(0.0128)
	Non-profit/non-governmental organization	0.0685***
		(0.0202)
	Other (please specify)	0.0448
		(0.0328)
	Prefer not to say	0.0825***
		(0.0298)
	Private sector	0.0370***
		(0.0127)
	Retired	0.0778***
		(0.0260)
	Student	0.00102
		(0.0168)
	Unemployed	0.0417***
		(0.0113)
Political Leaning (Reference = Greens)	Christian Democrat/Conservative	0.0805***
		(0.0149)
	Liberal	0.0441***
		(0.00755)
	Other	0.0601***
		(0.00635)
	Prefer not to say	0.0670***
		(0.00725)
	Social Democrat	0.0497***
		(0.00858)
	Children	-0.0168***
		(0.00324)
	Adults	-0.00759*
		(0.00436)
	Female	0.0225**
		(0.0105)
	Composite score of all environmental efforts	-0.0290***
		(0.00441)
	Daily Distance Driven	0.00485
		(0.00471)
	Car is a preferred mode of transit	-0.0121
		(0.0127)
	Observations	3,776

Table A2: Model with different environmental efforts

	VARIABLES	Interest in EVs (0/1)
	Environmental Efforts	
	Installed Energy Efficiency	0.0606***
		(0.0227)
	Invested in Solar	0.0519
		(0.0382)
	Changed diet to eat less meat and more local produce	0.0829***
		(0.0152)
	Increased my waste recycling efforts	0.168***
		(0.0231)
	Decreased my household water use	-0.0158
		(0.0195)
	Household Income	0.0155***
		(0.00353)
Occupation (Reference = Academics)	Government	-0.0699***
		(0.0179)
	Non-profit/non-governmental organization	-0.190***
		(0.0527)
	Other (please specify)	-0.127
		(0.0793)
	Prefer not to say	-0.195***
		(0.0518)
	Private sector	-0.0945***
		(0.0187)
	Retired	-0.198***
		(0.0473)
	Student	-0.0338
		(0.0263)
	Unemployed	-0.118***
		(0.0335)
Political Leaning (Reference = Greens)	Christian Democrat/Conservative	-0.165***
		(0.0355)
	Liberal	-0.0942***
		(0.0145)
	Other	-0.131***
		(0.0142)
	Prefer not to say	-0.159***
		(0.0173)
	Social Democrat	-0.100***
		(0.0195)
	Children	0.0320**
		(0.0160)
	Adults	0.0199
		(0.0143)

VARIABLES	Interest in EVs (0/1)
Female	-0.0637***
	(0.0188)
Daily Distance Driven	-0.0136
	(0.00977)
Car preferred mode of transportation	0.0483
	(0.0341)
Observations	4,658

Table A3: Model with different vehicle characteristics included in the analysis

	VARIABLES	Interest in EVs (0/1)
	Vehicle Characteristics	
	Importance of Speed and Acceleration	0.0156**
		(0.00751)
	Importance of Size and Comfort	0.0121**
		(0.00612)
	Importance of Ease of Operation	0.0519***
		(0.00666)
	Importance of Safety	0.0271
		(0.0171)
	Importance of Fuel Economy	0.116***
		(0.0159)
	Importance of Price	-0.00953
		(0.0195)
	Household Income	0.0175***
		(0.00397)
Occupation (Reference = Academics)	Government	-0.0761***
		(0.0159)
	Non-profit/non-governmental organization	-0.192***
		(0.0473)
	Other (please specify)	-0.127
		(0.0773)
	Prefer not to say	-0.180***
		(0.0481)
	Private sector	-0.0955***
		(0.0198)
	Retired	-0.203***
		(0.0412)
	Student	-0.0406*
		(0.0212)
	Unemployed	-0.120***
		(0.0280)
Political Leaning (Reference = Greens)	Christian Democrat/Conservative	-0.156***
		(0.0310)
	Liberal	-0.0997***
		(0.0107)
	Other	-0.136***
		(0.0139)
	Prefer not to say	-0.163***
		(0.0199)
	Social Democrat	-0.114***
		(0.0182)
	Number of Children	0.0330**
		(0.0163)

VARIABLES	Interest in EVs (0/1)
Number of Adults	0.0203 (0.0127)
Female	-0.0852*** (0.0190)
Composite score of all environmental efforts	0.0546*** (0.00386)
Daily Distance Driven	-0.0114 (0.00941)
Observations	4,644

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